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MECHANICAL DESIGN ENGINEERING
NASN/UNIVERSITY ADVANCED DESIGN PROGRAM

LUNAR STONE SAW

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An Equal Education and Employment Opportunity Institution

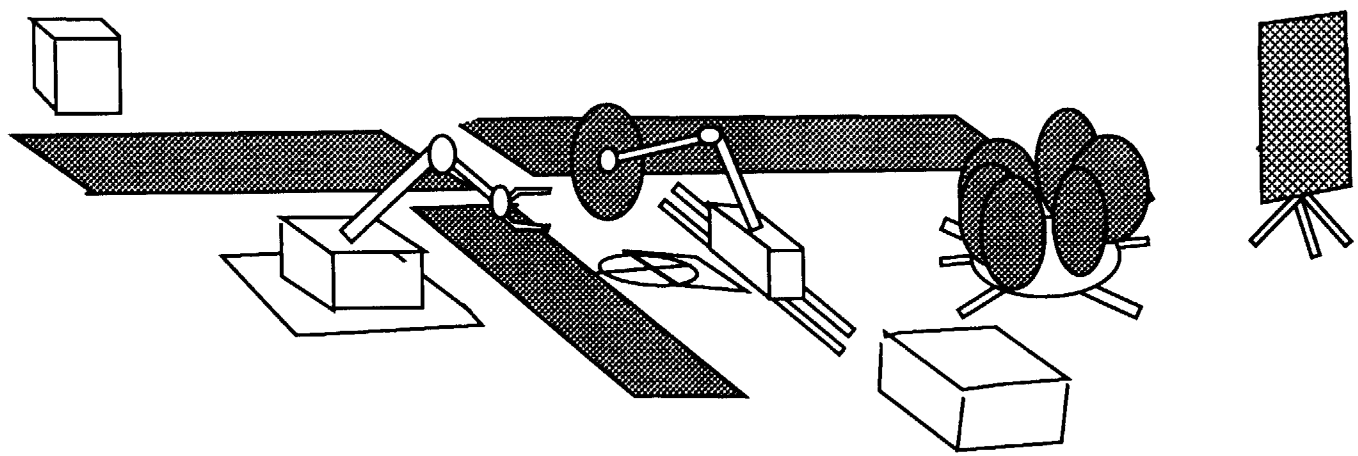
A Unit of the University System of Georgia

ABSTRACT

This project addresses the problem of cutting lunar stones into blocks to be used to construct shelters to protect personnel and equipment from harmful solar radiation.

This plant will manufacture 6"X1'X2' blocks and will be located near the south pole to allow it to be in the shade at all times. This design uses a computer controlled robot, a boulder handler that uses hydraulics for movement, a computer system that uses 3-D vision to determine the size of boulders, a polycrystalline diamond tipped saw blade that utilizes radiation for cooling, and a solar tower to collect solar energy. Only two electric motors are used in this plant because of the heavy weight of electric motors and the problem of cooling them. These two motors will be cooled by thermoelectric cooling. All other motors and actuators are to be hydraulic.

The architectural design for the building as well as the conceptual design of the machines for cutting the blocks are described in this report.



CONCEPTUAL DESIGN FOR A SYSTEM TO CUT
LUNAR STONE INTO RADIATION SHIELDING

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1.0 PROBLEM STATEMENT

1.1 BACKGROUND

Due to the extreme temperature swings between night and day and the radiation coming from the sun, equipment on the lunar surface needs protection from exposure. Since the cost of transporting premanufactured buildings is very high (approximately $25,000/pound), a way must be devised to use lunar material to construct these structures.

The general objective is to reconfigure boulders found on the lunar surface so that they could be used to construct enclosed shelters with walls approximately two meters in thickness. This thickness is necessary to protect the stored equipment from radiation. Plans will have to be made for the type and design of these structures as well as the tools that will be cutting the boulders.

1.2 PERFORMANCE OBJECTIVE

The cutting plant will have to be able to produce enough blocks to construct one building per lunar dayfrom rocks and boulders of various sizes, Thus the computer system must have the capability of scanning the the rocks to determine their size. Also, since personnel will only be available approximately two weeks out of the year, this system will need to be very nearly maintenance free and capable of operating for extended periods of time

1.3 CONSTRAINTS

Several constraints apply when working on the lunar surface:

* The cutting machine must be as lightweight and small as possible so as to keep down the initial transportation cost.

* The equipment must be capable of withstanding wide swings in environment temperature (-240 F to 250 F) and exposure to intense solar radiation.

* The equipment must be capable of operating in a vacuum - all lubricants must be sealed so that they do not evaporate.

* All equipment must be able to withstand the abrasiveness of the lunar soil.

* The energy source will be primarily solar.

* The saw must be capable of cutting blocks approximately 2' by 1' by 6" .

* The plant must be designed to keep the machines from getting too hot.

* The saw must be able to process boulders which have a size of up to six feet in any diameter.

2.0 DESCRIPTION OF SOLUTION

The plant designed by this group is described in the following pages. After boulders are gathered by lunar rovers, a vision computer system will be used to scan the boulders and reject the ones that have any dimensions that exceed 6 ft. or that weigh more than 500 lbs. This computer system will also decide exactly how to cut the boulder to get as many blocks out of the boulder as possible. Two dimensional versions of computer systems such as this are in wide use in the textile industry where they are used to decide how to cut fabric so as to waste as little of the fabric as possible. Combining this technology with 3-D computer vision should result in a system adequate for our purpose.

After sizing, the boulder will be transported to the cutting operation via a conveyor network. Here the boulder will be picked up by the boulder handler which is simply a "backhoe like" hydraulic arm controlled by a computer . This handler, together with the turntable, has the ability to manipulate the boulder in any way needed to get the necessary cuts to shape the boulder into a block. If this boulder is a large one, the resulting block could be quite large. In that case, this block will be cut into smaller ones with the saw while it is sitting on the turntable.

The saw will consist of a robot similar to ones used in industry for such jobs as welding and auto assembly. Air Technical Industries' model RT-X7K was found to be a robot similar to the one needed for this plant. On the end of this robot will be a hydraulic motor and a diamond tipped circular saw blade. The boulder will be held stationary and the saw will be manipulated since the saw is lighter and thus requires less energy to be moved. This robot is sufficiently dexterous so that no other robot is necessary to preform the blade change operation. Cool blades are stored in a carousel to the west of the robot for easy access. See page 35 for general layout of cutting area.

Any debris collected in this area is to be conveyed to a lunar rover and discarded. This debris may be in the from of fines form the saw or large chunks of lunar rock cut from the "raw" boulder . Also note the hydraulic sweeper to the south of the turntable. It is used to clean any fines from this turntable. Debris falling beyond any of these conveyors will have to be cleared during shut-down maintenance periods.

Once the blocks are cut to the proper size, they are placed on the accepts conveyor and sent to the storage area. From there they are picked up by the rovers responsible for constructing the building. Details concerning this building are part of the scope of this project are also presented in this paper.

In this design the main source of trouble was dealing with rejection of heat built up by the electric motors that are responsible for generating the hydraulic pressure that operates almost everything else. This problem was solved by use of solid state cooling and radiation as well as locating the entire plant in an area that is shaded at all times (the south pole). The extra cost of transporting this equipment to this pole location is more than offset by the savings brought about by reducing the cooling requirement and allowing the plant to be near its source of DC electric power--the solar towers at the south pole.

3.0 DETAILS OF SOLUTION

3.1 STRUCTUAL DESIGN OF BUILDING

The beginning stages of the project design were focused on the type of building structure most appropriate for the solution of the problem. The type of structure would dictate the shape of the block that is to be cut. For example, some structures such as the igloo or semi-circular arch would have to have a more complex block shape. The igloo block would need ends cut at angles to the perpendicular of the sides. The semi-circular arch block would need some type of curvature cutting which would greatly increase the complexity of the cutting process. On the other hand, structures such as the equilateral arch or a cubic style building allow for a simple rectangular shape block.

Research into various architectural designs was conducted. Different possible solutions were examined for their appropriateness and practicality to the problem. Various factors were considered in the study and comparison of the structures. Factors, such as complexity of the block shape required, ease of building construction, and the amount of stone required, were examined and fitted into a matrix format to allow for a mathematical approach to the decision of the type of structure to build. After comparison of the factors and structures, the equilateral arch design proved to be the best solution to the problem.

The three candidates for building cement were epoxy cement, molten sulfur, and molten rock. Epoxy resin has the necessary strength, but must stand up to vacuum, hard radiation, and extreme temperature changes. Molten rock also has the necessary strength to serve as cement, but would require temperatures of around 1400-2000 degrees centigrade to melt.

Sulfur has none of these problems. It melts at 119 degrees centigrade, which is a little above the maximum daylight temperature of the moon. Sulfur is also theorectically plentiful on the moon near the lunar volcanoes. This eliminates the the need to haul it up from Earth. The sulfur cement could be applied as a paste or spray to a surface.

3.2 SAW/CUTTING PLANT

The first problem that had to be solved for this saw was exactly how the wide range of boulder sizes would be handled by the robots to get all the cuts required. The first layout is sketched in Appendix 4. A thorough analysis of this layout revealed that it was far too complex and clumsy. Also, it was not capable of manipulating the boulder in a way that would allow all cuts. The layout finally chosen is shown on page 35 in the Graphics/Figures section. The following paragraphs describe each machine in the cutting plant in detail.

3.2.1 Electric/Hydraulic Motors

Once the basic layout was decided on, specific problems had to be addressed. How are the electric motors going to be cooled? How are they going to operate (AC, DC, brushless)? What problems would their weight cause? These problems were answered by referring to NTIS papers on electric motors. It was impossible to find any information on the design of electric motors of the size needed for this operation. It was not believed that existing designs could simply be upscaled since the small motors that have been designed did not provide for cooling since they were generally small speed, small H.P. motors. Fortunately, large H.P. hydraulic motors were found while searching for a compact hydraulic actuator for the boulder handler. These motors offer several significant advantages over electric motors. They can operate in a vacuum without any design changes; they can be kept at their operating temperature by simply heating or cooling the hydraulic fluid; they weigh only about one-fourth as much as electric motors; and they operate at lower rpm with a higher torque than electric motors. The 60 H.P. motor used for the saw will be model SMAU 21 by Rotary Power, Inc.

The significant weight reduction is important since the 60 H.P. saw motor will be manipulated by the robot arm which has a weight limit of 2000 lbs.

3.2.2 Robot:

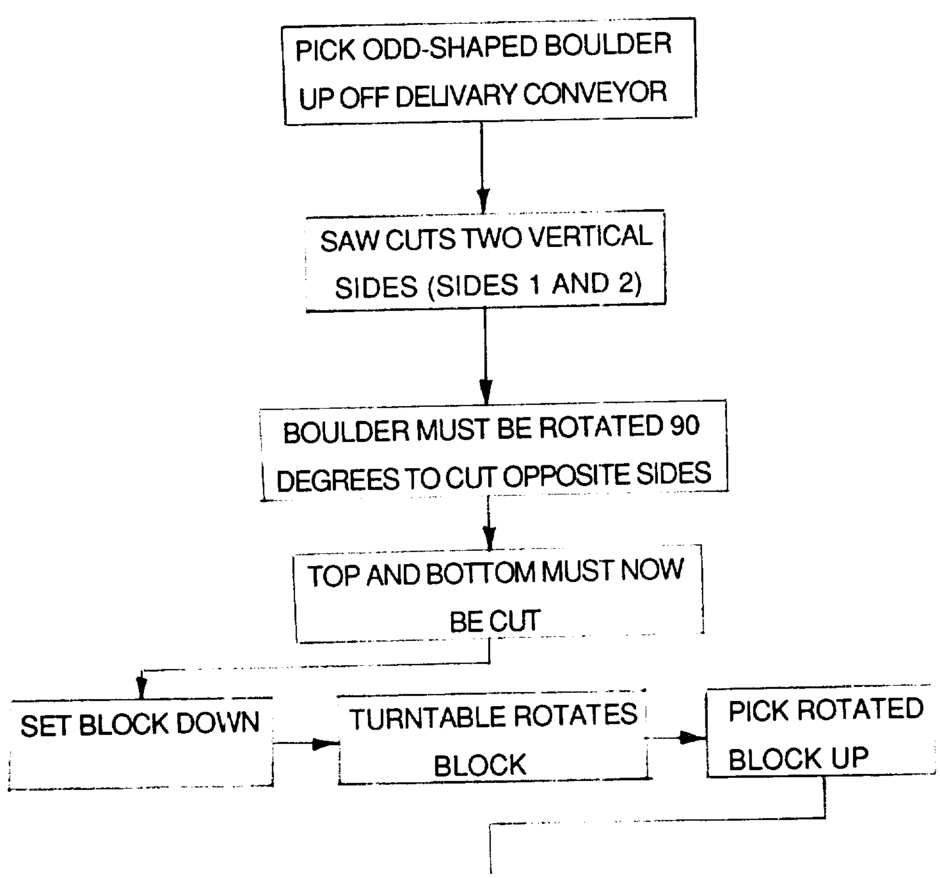
A robot was found that could be used to manipulate the saw itself. Model RT-X7K from Air Technical Industries has all the characteristics needed. The only changes in design of the robot were to eliminate the rotational joints in the end of the arm and to pressurize the chassis so that the stepper and servo motors can be cooled by convection. To achieve this, all joints would have to be sealed to withstand high pressures. Note the

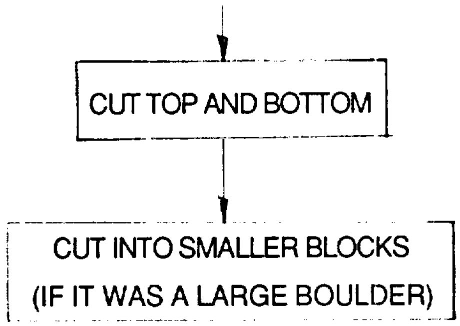
shape of the rails that the robot rides on. These are angled on the top so that debris will not collect and cause wear. See page 29 for drawing of robot.

3.2.3 Hydraulic Boulder Handler:

To get the hand of the hydraulic boulder handler to turn the required 90 degrees, several arrangements were considered. The design was limited to a width of 4" so as not to interfere with the saw blade when it is cutting a boulder 4" wide. Using a beveled gear arrangement with a small electric motor was considered first. This was dropped because a decision was made not to use electric motors and because a motor with a 4" diameter could not be found. A hydraulic rack and pinion assembly was found while searching through the VSMF literature for a hydraulic motor small enough to do the job. These were the size we needed (3 5/8 " to be exact) and could be ordered off the shelf. The one for the boulder handler is to be model STR9 manufactured by Parker, Inc. A larger, but similar one was used to control the turntable. It will have a 180 degree rotation instead of just 90 degrees. See page 27 in the Graphics/Figures section for details of the hydraulic boulder handler. Hydraulic motor model MH 67 by Rotary Power, Inc. will be used to raise and lower the primary arm of the boulder handler.

A flow chart of the operation of the boulder handler and robot is shown below.





The static structural calculations for this handler are in Appendix 1.

3.2.4 Turntable:

Since the handler lacks the ability to flip the boulder, a turntable was placed beneath the saw to perform this movement. This was found to be simpler than putting an axis joint on the boulder handler. As mentioned before, this turntable would be actuated by a hydraulic rack and pinion. This turntable can be seen on page 24. Note that this turntable is slotted along two diameters to allow the block to be cut while rested on top of it. This turntable is 4 ft. in diameter to allow for the larger boulders.

3.2.5 Sweeper:

To clean fines off the turntable, a hydraulic piston actuated sweeper will be located on the south side of the turntable. After each boulder is finished, it will deploy and sweep the fines to the debris conveyor.

3.2.6 Hydraulic pumps/Solid State Motor Cooling:

The only electric motors to be used on this project will be the ones for the hydraulic pumps. These pumps will put the hydraulic fluid under a pressure of 3000 and 5000 psi. To do this, one 200 H.P. motor and one 300 H.P. motor will be required. These are DC brushless motors cooled by a solid state cooler. This cooler will consist of a solid metallic block (copper) which acts as a heat sink. When current is passed through a solid state cooler, the metal heat sink in contact with the motor is cooled and the heat is carried to a surface specially designed to radiate heat into deep space. Solid state cooling works on the Peltier Effect where a circuit composed of two dissimilar conductors is used to transport heat from one junction to another. Reference 1 goes into details about this thermoelectric device. See page 35 for a drawing showing the motors,

cooler, and pumps. These pumps will be responsible for supplying hydraulic pressure for the entire plant.

3.2.7 Solid State Cooling/Resistive Heating of Fluid:

For proper operation, all hydraulic motors, pumps, and rack and pinion actuators must be kept between -40 degrees F and 170 degrees F. This is easily and remotely achieved by cooling the fluid with a solid state cooler and a resistive heater. This is a big advantage over the use of electric motors and actuators which must be cooled and heated by devices located on these machines instead of one central heat pump. During idle times (such as during maintenance periods) the fluid and machines may go below the -40 degree F limitation. To keep this from preventing start-up, resistive heaters will be placed in the cooling/heating exchanger located near the hydraulic pumps. This exchanger will also have the ability to remove heat from the fluid during normal operation to keep the machines under their temperature ceiling of 170 degrees F. All fluid pumped to the plant will pass through this block. See drawing on page 35 .

3.3 Conveyor System

3.3.1 Accepts Conveyor

The accepts conveyor, Figure 3, is the conveyor that carries the finished bricks to some location away from the saw. This conveyor is eight feet long. If the bricks need to be transported further than eight feet, then additional conveyors of the same design can be placed adjacent to each other allowing for further transport since the spools at the end of the conveyor have such a small diameter. This allows a brick to easily run from one conveyor to the next. The conveyor is of a conventional design which utilizes a compressed spring to provide the necessary tension in the mat.

3.3.2 Debris Conveyor

The debris conveyor is simply a modified accepts conveyor. One modification is in the spring to be used. Since the debris (scrap rock) that will be discarded may be slightly larger than a finished brick, the conveyor will need a spring that has a slighly larger spring constant to provide adequate tension in the mat. Another modification that needs to be made is the addition of a set of walls. These walls would be mounted on the side of the conveyor in order to keep debris from falling off of the conveyor when the debris drops from the saw.

3.3.3 Delivery Conveyor

The delivery conveyor will be used to bring the uncut boulders to the saw. Again, this conveyor is only a slight modification of the accepts conveyor. It will also need a larger spring constant in its spring. This is necessary, because some of the incoming boulders may weigh as much as four hundred pounds, therefore increased tension will be needed in the mat.

3.3.4 Mat Material and Design

The material that will be used for the mat will have to withstand the sticky dust particles and the extreme temperatures found on the moon. Therefore, some type of tire material should be used. This material should be similar to the material used for instance on the lunar dump truck.

The mat must also have a specialized pattern on its underside to match the gearing patterns of the three spools that drive the mat. The two outside spools will be geared to drive the mat while the inner spool will be geared in order to keep the mat from running off of the two outside spools.

3.4 DIAMOND TIPPED CIRCULAR BLADE

3.4.1 Material

Since we have chosen the method of cutting with a circular saw, a large diameter blade is required. This large diameter will help conduct the heat generated while cutting, away from the cutting edge of the blade. The large volume will act as a sink to "hold" the high temperatures. An eleven foot diameter blade is now being used in West Germany to cut granite and although their blade is water cooled, we know that if the temperature can be controlled the circular saw method will work.

To be able to cut hard abrasive rock at very high temperatures, careful attention needs to be taken when choosing the blade material. Obviously, we first looked towards the high speed tool steels. Since we know that we will be operating at very high temperatures, the most important property of the material is its hot hardness. Hot hardness is the ability of a material to retain its hardness at elevated temperatures. The hot hardness bears a much more direct relationship to cutting ability than the hardness at room temperature. The second component to cutting ability is resistance to wear. Wear resistance of high speed steels is affected by the matrix hardness and composition. In practically any given high speed steel, wear resistance strongly depends on hardness of the steel and higher hardness, however achieved, is an aim when highly abrasive cutting conditions are encountered. So, hot hardness and high wear resistance are the two most important parameters when choosing a high speed tool steel, which will operate at high temperatures in extremely abrasive conditions.

With consideration of the above parameters, we will make our blade from a Tungsten high speed tool steel, AISI T4. T4 has a tempering temperature of 1100 degrees F. At 1100 degrees T4 has a Rockwell hardness of 60 compared to 66 at room temperature. This hot hardness is the highest of all the tool steels. T4 is also the fourth highest out of approximately 80 tool steels in the category of resistance to wear. T4s high hot hardness and resistance to wear were the two major factors in choosing this Tungsten alloy. For a complete detail listing of T4s properties see Table A. A decision matrix of the choices of tool steels is given in Appendix 2.

3.4.2 Blade Design

The saw blade is to be seven feet in diameter and one quarter inch thick. The blade will be tipped on each tooth with diamond segments. For a detailed design of the saw blade see figure 5.0. The segments will be of the polycrystalline structure. Polycrystalline diamond compacts are made by sintering diamond powder under pressures in the 10 GPa range at high temperatures. This random orientation in the segments, provides uniform wear resistance in all directions and eliminates the planes

of easy cleavage that frequently result in premature failure of single-crystal diamond cutting tools. Due to the high temperatures this blade will be operating at, these segments will have to be laser welded to the blade instead of conventional welding or silver-soldering. See figure 7.0 for a detailed design of the these segments. These segments are to be of the sandwich construction with stepped arrangement of the flanks. These stepped segments reduce the contact area between the segments and the kerf and thus help reduce both wandering from the required line and current consumption. Also, when designing this blade and its tolerances, we have to consider thermal expansion because the blade will be subject to very large temperature gradients. T4 has a thermal expansion coefficient of 6 6E-6 in/in when the temperature range is from 68 to 1000 degrees F. This thermal expansion will meet our design specifications.

3.4.3 Temperature Control

The limiting factor for the saw blade is temperature. Care must be taken to assure the blade does not reach over 1000 degrees F. and this temperature rise is as slow as possible. Since the tempering temperature of T4 is 1100 degrees F. the saw will be equipped with an electronic temperature sensor. If the blade temperature reaches 1000 degrees F. the cutting process will be stopped temporarily. While stopped, the cutting blade will be changed with a cool blade from a carousel which is located next to the cutting machine. Various means have been implemented to help keep the cutting plant and saw blade as cool as possible. First the plant will be located near the south pole. It is theorized that near the south pole there are areas of constant darkness. The temperatures in these dark areas is about -240 degrees F. Another means of cooling the blade is available when a hot blade is changed and stored in the carousel. See figure 8.0 for a detailed design of the carousel. When the hot blade is put into the carousel, two large aluminum blocks will be clamped to the blade to help conduct some of the heat away from the blade. Also, while in the carousel we will take advantage of the radiant properties of the hot steel. The emissivity of rough oxidized steel is approximately .80. At 1000 degrees F. the heat loss to space due to radiation is 70,000 watts. See Appendix 1 for more temperature and heat transfer calculations. We have theorized by talking to many experts in the stone cutting and saw blade manufacturing industry and taking into account our temperature control efforts, a hot blade will need to be changed with a cool blade approximately every 1.5 hours of cutting. Since there will be five spare blades in the carousel each blade will have at the <u>least</u> 8 hours to cool down before it is used again.

TUNGSTEN HIGH SPEED TOOL STEEL

AISI T4

MATERIAL PROPERTIES

ANNEALING TEMPERATURE	1600-1650 F
HARDENING RESPONSE	DEEP
HARDNESS (HRC)	62-66
RESISTANCE TO SOFTENING	HIGHEST
RESISTANCE TO WEAR	VERY HIGH
DENSITY	.313 LB/IN^3
THERMAL EXPANSION 68-1000 F	6.6E-6 IN/IN
AVG. THERMAL CONDUCTIVITY	22.0 W/M-K
MACHINABILITY RATE	35 - 40
TEMPERING RANGE	1000-1100 F
SPECIFIC GRAVITY	8.68
ULTIMATE TORQUE	425 IN-LB
YEILD STRENGTH	450 KSI
HOT HARDNESS (1000 F)	60

COMPOSITION (A). %

CARBON	.70-.80
MAGNESIUM	.10-.40
SILICON	.20-.40
CHROMIUM	3.75-4.00
NICKEL	.30 MAX
MOLYBDENUM	.40-1.00
TUNGSTEN	17.50-19.00
VANADIUM	.80-1.20
COBALT	4.25-5.75

Table A

3.5 Vision Computer System

3.5.1 Detection

The plant will use a computer system that will make a three dimensional model of a boulder by use of laser detection. First, it will determine if the boulder meets the necessary size requirements for the saw. Next, the computer will tell the saw how to cut the boulder in order to get the maximum number of bricks out of the boulder.

3.5.2 Plant Coordination

The computer system also coordinates the movement of the saw and the conveyors. When a scrap piece of rock is cut off of the boulder, the computer system will activate the debris conveyor. When a finished brick is placed on the accepts conveyor, the computer system will activate the accepts conveyor. The computer system will also activate the delivery conveyor when another boulder is needed for processing.

The computer system also works the carousel and hydraulic system on the saw. When the sensor on the carousel reads 1000F, the computer activates the carousel which replaces the blade. The computer system also coordinates the movement of the hydraulic arm. When the necessary cuts, determined by the computer vision, have been made; the computer directs the necessary movement of the hydraulic arm.

3.6 SOLAR POWER (PHOTOVOLTAICS)

The entire system will be supplied with power from solar panels which contain silicon solar cells that convert solar energy to electricity. This conversion process is known as photovoltaics. (See figure 9)

3.6.1 Solar Panel Wiring

The cutting site will be located in a crater at the south pole of the moon. The solar collectors will be located outside the crater to allow them to be in continuous sun. Solar towers will be constructed that will raise the collectors above the ground to allow for more direct sunlight since the sun will most likely be close to the horizon.

3.6.2 Power Requirements

The pumping station for the hydraulic motors will require power to supply two dc motors, one is a 200 H.P. motor and the other is 300H.P. The total power required by the pumping station is thus 500 H.P. or 373 kw. There will be a 20% allotment of power added to the total to allow for inefficiencies and losses due to wiring resistance, power conditioning equipment, panel mismatches, and high temperatures due to the intense solar radiation. This totals up to 447.6 kw of power for the pumping station. An output of 500 kw will be supplied by the solar panels. This will leave 52.4 kw for lighting, camera equipment, and other auxiliary power, as well as small expansions and modifications in the future.

3.6.3 Array Output

The panels will be arranged in an array fashion, where each array will be divided into 20 sub-arrays. There will be 5 towers with each holding 4 sub-arrays. Each sub-array will supply 25 kw of power. Each sub-array will be made up of 10 strings of 20 modules, with the strings connected in pairs. The formation of the array with the 25 kw sub-arrays provides a convenient module size with which to build up a larger power source in the future. In addition, this type of set up provides a degree of reliability in the event of sub-array failure - only a 5% loss of output per sub-array.

3.6.4 Solar Panel Wiring

The modules of each sub-array will be linked together in a series of strings, with each sub-array being connected in parallel. This arrangement of wiring and terminal blocks will help facilitate the location of faults in the event of failure. The strings of modules in series will need to be protected with diodes to prevent reverse currents which may result from damaging hot spots in the panels.

The extra power is provided due to the many types of losses that will occur throughout the system. Mismatch losses will arise from the fact that the current-voltage characteristics of individual photovoltaic modules vary. When the modules are linked together in a series of strings, the combined current-voltage characteristic from one string will in general differ from the others to which it is linked in parallel.

3.6.5 Power Conditioning Unit

A power conditioning unit will need to be installed into the wiring system (see figure 9). This unit will monitor and control the power coming in from the photovoltaic array, making sure that the maximum power is extracted from the panels. The unit will also maintain a steady flow of power from the array. Surges in power may result from "hot spots" in the array structure, resulting in damage to the pumping motors and other equipment.

The conditioning unit will take the incoming dc voltage from the solar panels and convert it to two outputs. One output will be the power for the pumping motors. The two motors (one at 300 H.P. and one at 200 H.P.) will require 447.6 kw at 480v dc of power for operation. The other output will be the remaining power at 120v ac for lighting, camera equipment, and auxiliary power for items such as repair equipment.

3.6.6 Distribution Unit

Since power is required to be dispersed to more than the pumping station, a distribution unit will be needed (see figure 9). The distribution unit will take the output from the power conditioning unit and transfer the dc component to the pumping motors and the ac component to the lights and camera equipment. Situations such as emergencies and repairs may require power to operate equipment. Connections for either the dc or ac voltages will be located in the unit for these purposes. The unit will also function as a disconnect when the system is needs to be shut down. Separate disconnects will be installed for the pumping motors, the lighting and camera systems, and the auxiliary ac and dc power connections. This will allow for the operation of emergency and repair equipment as well as the lights and cameras while the rest of the plant is shut down.

3.7 Production Rate

The production rate for the saw has been estimated from production rates of limestone saws which were obtained from a field trip to the Sherwood Cut Stone Company. It takes approximately two minutes to cut a ten foot by four slab of limestone. Using this cutting rate, it was determined how long it would take to completely process a boulder with a diameter of six feet.

It is possible to get at least sixty-four bricks out of a boulder of this size; this requires that the saw make a four foot cube out of the boulder after the first six cuts. An additional eleven cuts would be required to produce the sixty-four bricks which gives a total of seventeen cuts. Assuming that each cut takes approximately two minutes, it takes thirty-four minutes of cutting time to produce the sixty-four bricks. A total of 19,500 bricks are needed to produce the desired building. This means that it takes approximately 173 hours or 7.2 days (earth days) of cutting time to produce enough bricks to make the building.

However, additional time must be added to account for the time needed for the hydraulic arm to readjust the boulder, change the blade, and place the bricks on the conveyor. Since it was virtually impossible to determine this additional time, an estimated 6.8 days were added to the 7.2 days of cutting time. This appeared to be a sufficient amount of time to allot for saw readjustments and placements, while it still gave a reasonable production rate.

The final production rate was fourteen days for 19,500 bricks. This would mean that one saw could produce enough bricks to build two of the proposed buildings in one lunar day (twenty-eight earth days).

3.8 CONCLUSIONS

It is believed that this design offers the best conceptual solution to the proposed problem. The main goal at all times in the design phase was to develop a plant that was feasible and realistic in its cost as well as in its assumptions about what could be expected from future technological advances. Avoided was any solution that used technology that was not already existent in some form.

By far the weakest link in the design of the saw plant was the computer system that will control and coordinate everything. Here we assumed that a computer system capable of seeing the "raw" boulder could determine how many blocks that a particular boulder could be cut into and then coordinate the movement of that boulder throughout the plant. There are many 3-D computer systems in use in industry as well as computers that are capable of keeping track of items being manufactured. A combination of these two technologies could lead to a system that is suitable for this application. Otherwise, the other machines are well within current technological possibilities.

3.9 RECOMMENDATIONS

There are many areas that could be improved by further study. Also, some ideas were discovered too late in the design phase to be incorporated into the design. One such idea was the use of a newly developed power source that works on a closed thermodynamic cycle. An ad was discovered on the back cover of the November issue of Aerospace Engineering magazine that described this machine and said that it could develop 250 KW of power. If this is true it could be just the thing to replace the two electric motors used in this report. This would remove the need for the solar towers. Other areas that need further study are described in the following paragraphs.

3.9.1 Saw

It is recommended that the design of the robot that manipulates the saw be looked into further. The conceptual design referred to Air Technical Industries' model RT-X7K but this robot is a little over-designed. For one thing, only three axes of motion are needed instead of the six this robot is capable of. It was selected as a starting point since it has the required reach as well as the payload capacity. Also, it should be investigated if pressurizing the chassis is all that is needed to make it work in outer space.

3.9.2 Blade

We recommend that a study be done to determine what type of blade temperatures will be achieved by cutting lunar rock with the method we have proposed. We have been unable to find any studies or research in this area. Our estimates of temperatures were achieved from consulting with experts in the stone cutting and saw blade manufacturing industry. We also consulted NASA heat transfer reports. Adjustments in our estimates can be accommodated by changing the number of blades available or the frequency with which the blades are alternated with each other.

3.9.3 Power Supply

Power sources such as nuclear power should be investigated due to the high power requirements of the system. A reactor near the cutting site would enable cutting at anytime without any battery storage or transportation of power over a long distance. Since the cutting plant requires an output of 5 kw of power, nuclear power would be more efficient and would require less maintenance. A huge number of solar towers would be required to hold the amount of area of solar cells that would be needed to produce 5 kw of power. The amount of weight that would have to be transported to the moon shows that another alternative would definitely be needed.

3.9.4 Material Handling/Conveyors

The material chosen for the mat was a tire material similar to the material previously used on space missions. This was chosen simply because this material could handle the temperature and abrasive surface found on the moon. Additional research and testing should be done in this area however. Other materials that can handle lunar conditions should be explored, tested, and evaluated. Furthermore, the material should also be able to have the pattern needed for proper gearing formed on its interior surface.

Another area concerning the conveyor that should be looked at, is the time required for readjustment of the hydraulic arm, placement of bricks, and reloading of blades. It seems highly possible that the production rate could be sufficiently faster. The hydraulic arm should function faster than the time allotted in the production rate estimation. This would mean that more than two buildings could be produced per lunar day.

3.10 ACKNOWLEDGEMENTS

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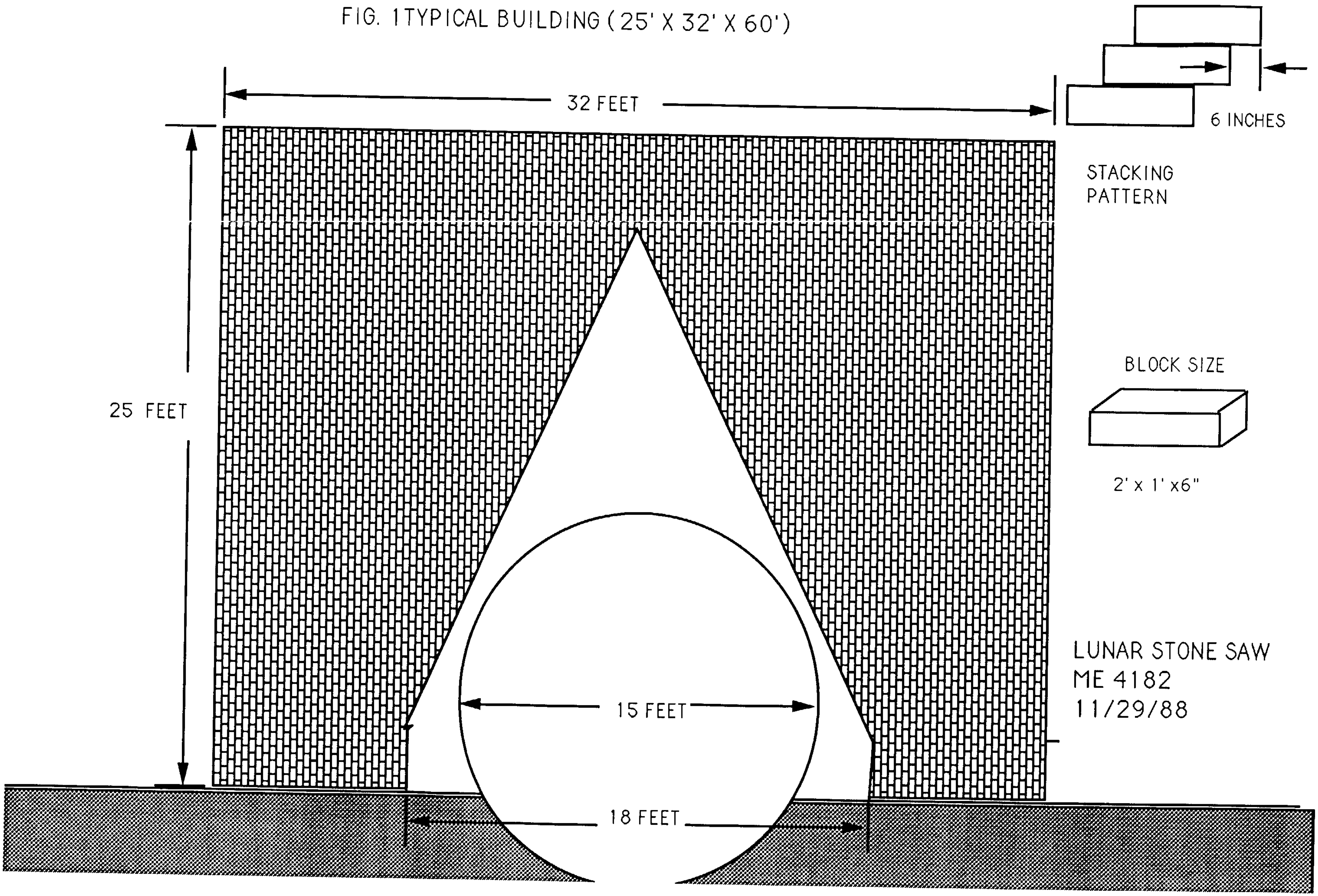
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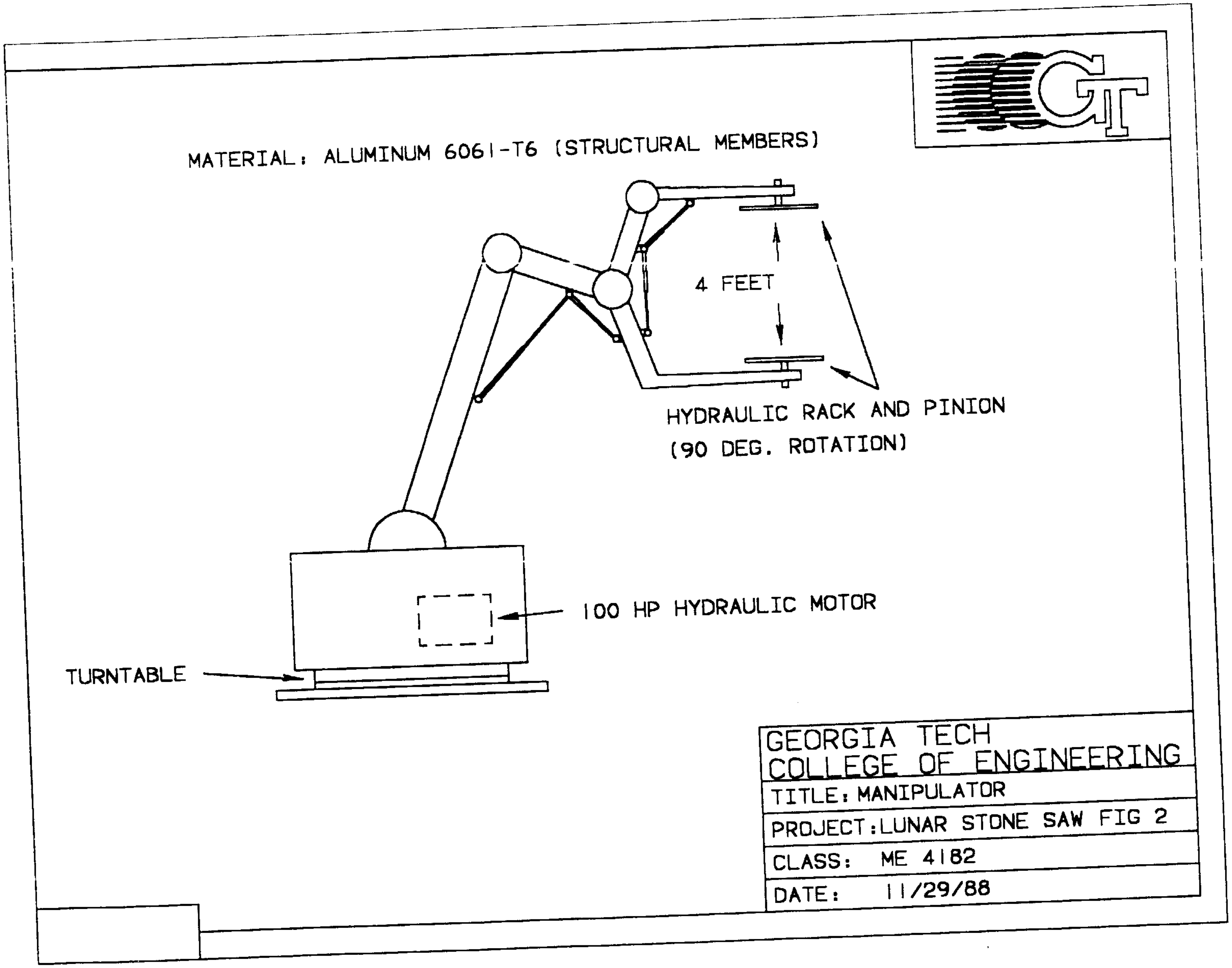
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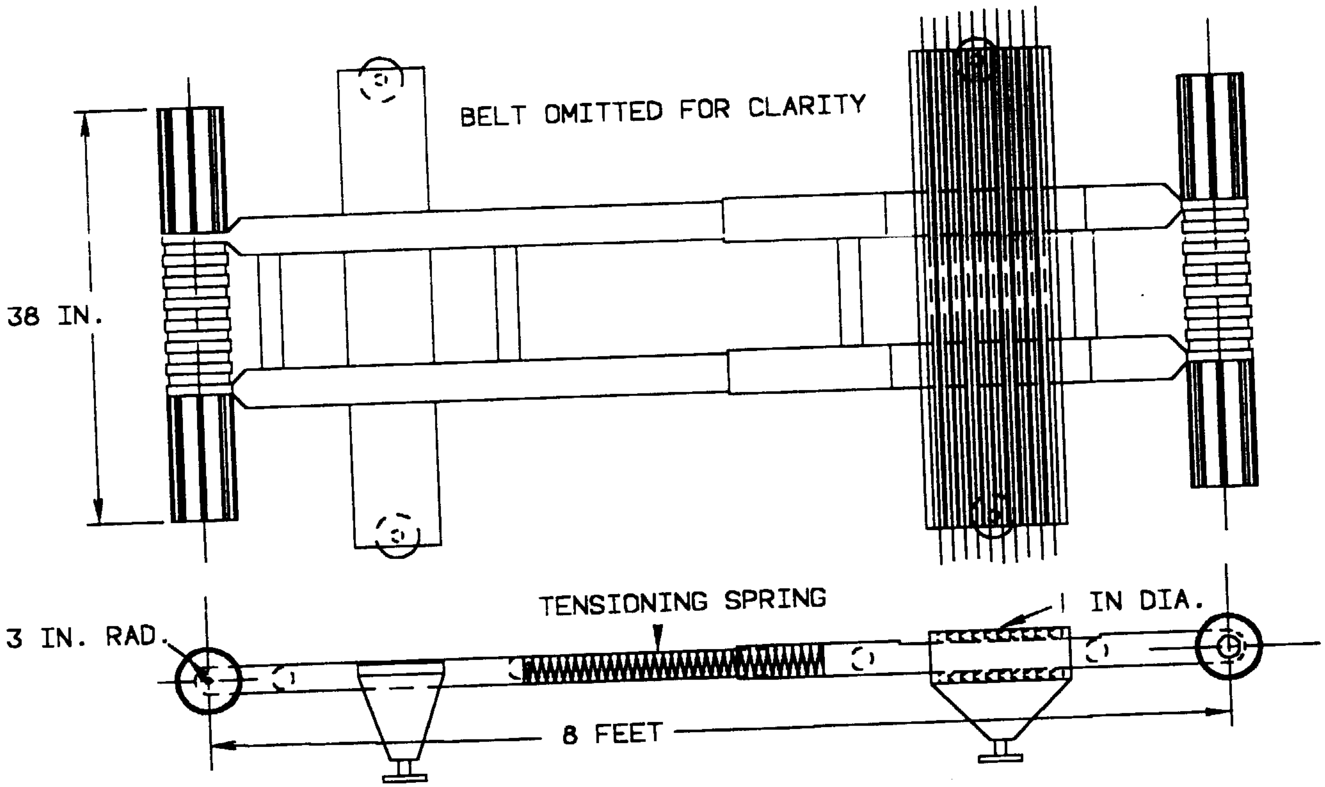
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3.12 GRAPHICS/FIGURES

FIG. 1TYPICAL BUILDING (25' X 32' X 60')




MATERIAL: ALUMINUM 6061-T6 (STRUCTURAL MEMBERS)
4 FEET
HYDRAULIC RACK AND PINION
(90 DEG. ROTATION)
100 HP HYDRAULIC MOTOR
TURNTABLE
GEORGIA TECH
COLLEGE OF ENGINEERING
TITLE: MANIPULATOR
PROJECT: LUNAR STONE SAW FIG 2
CLASS: ME 4182
DATE: 11/29/88



FRAME MATERIALS: ALUMINUM 6061-T6

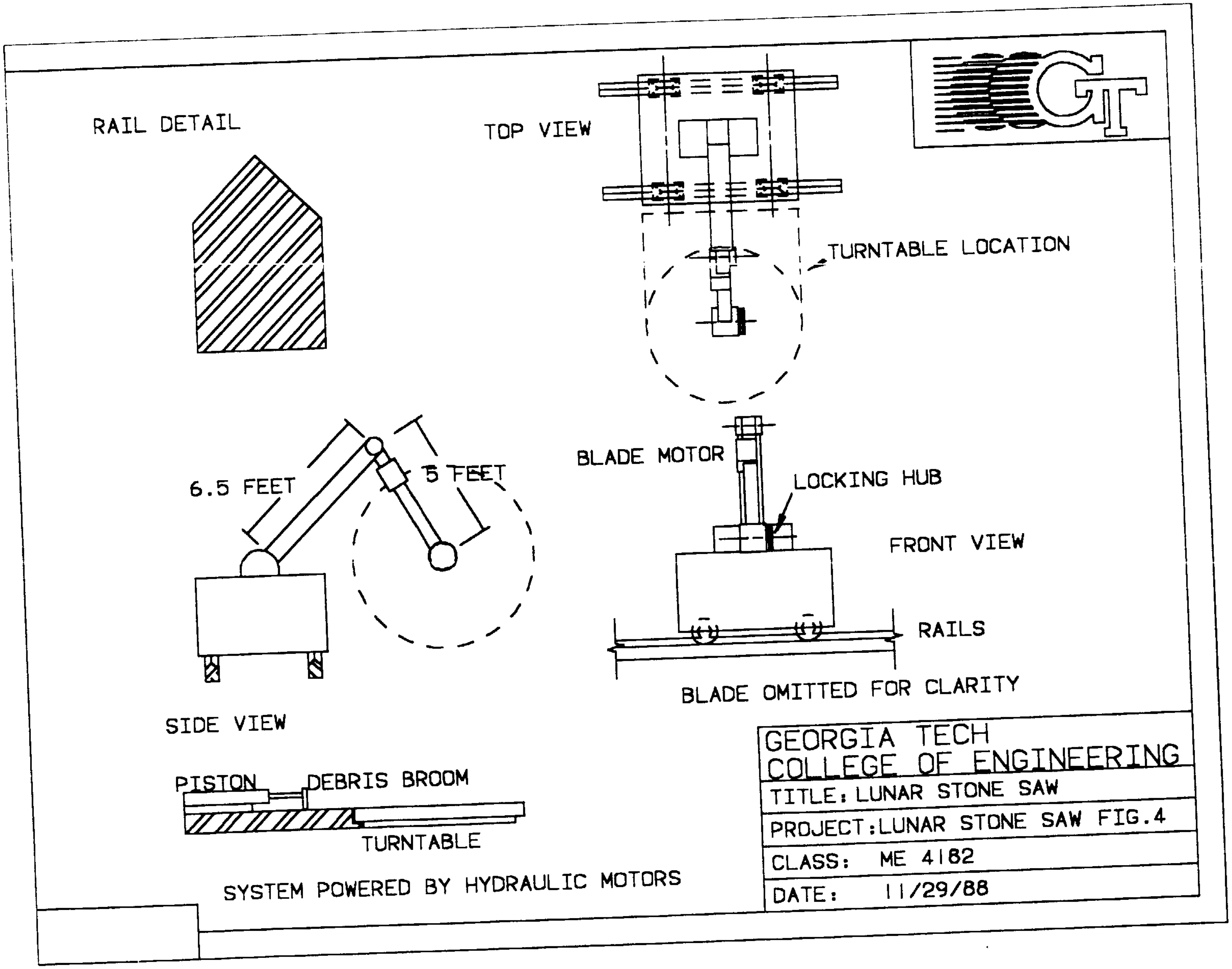
GEORGIA TECH
COLLEGE OF ENGINEERING

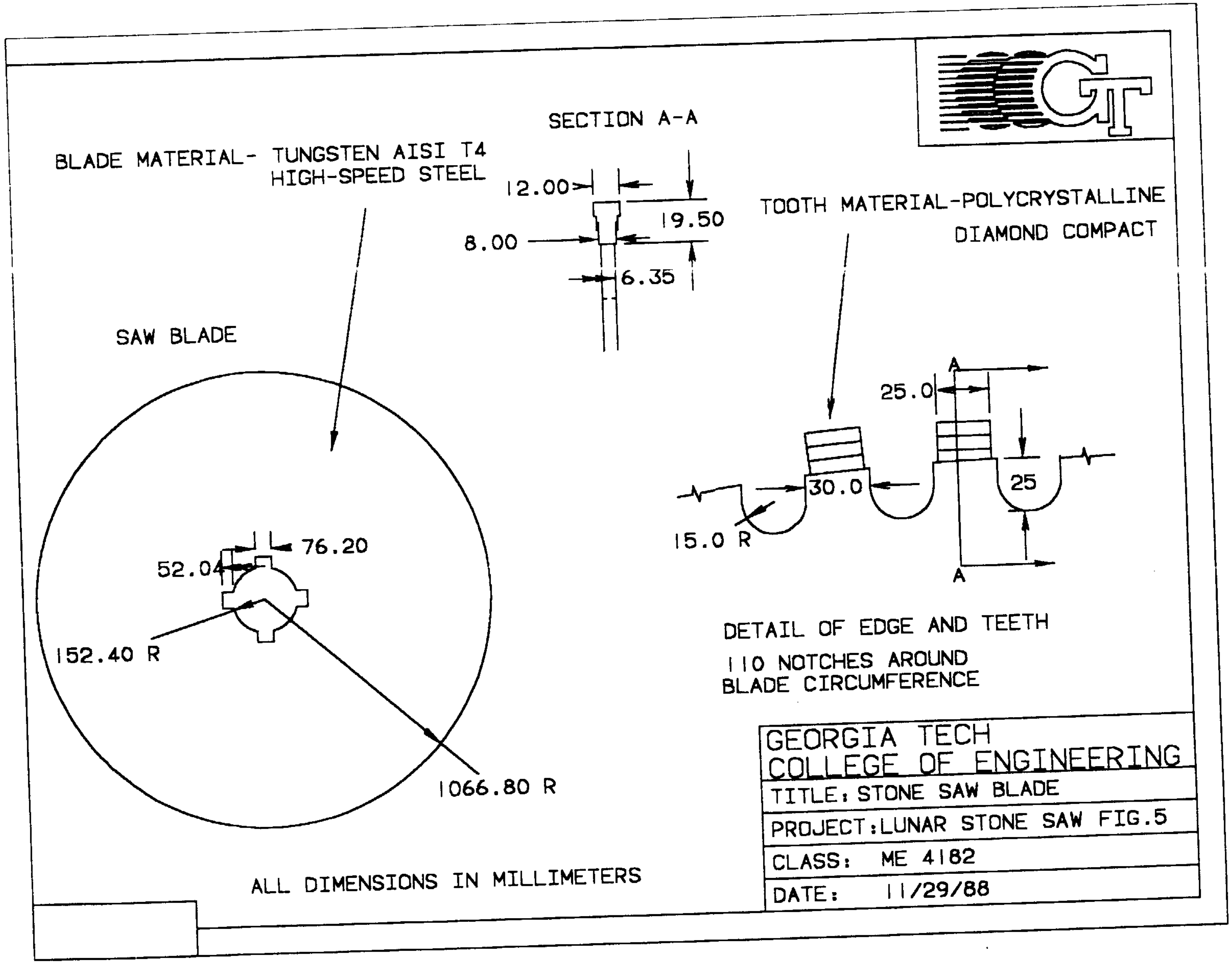
TITLE: CONVEYOR BELT

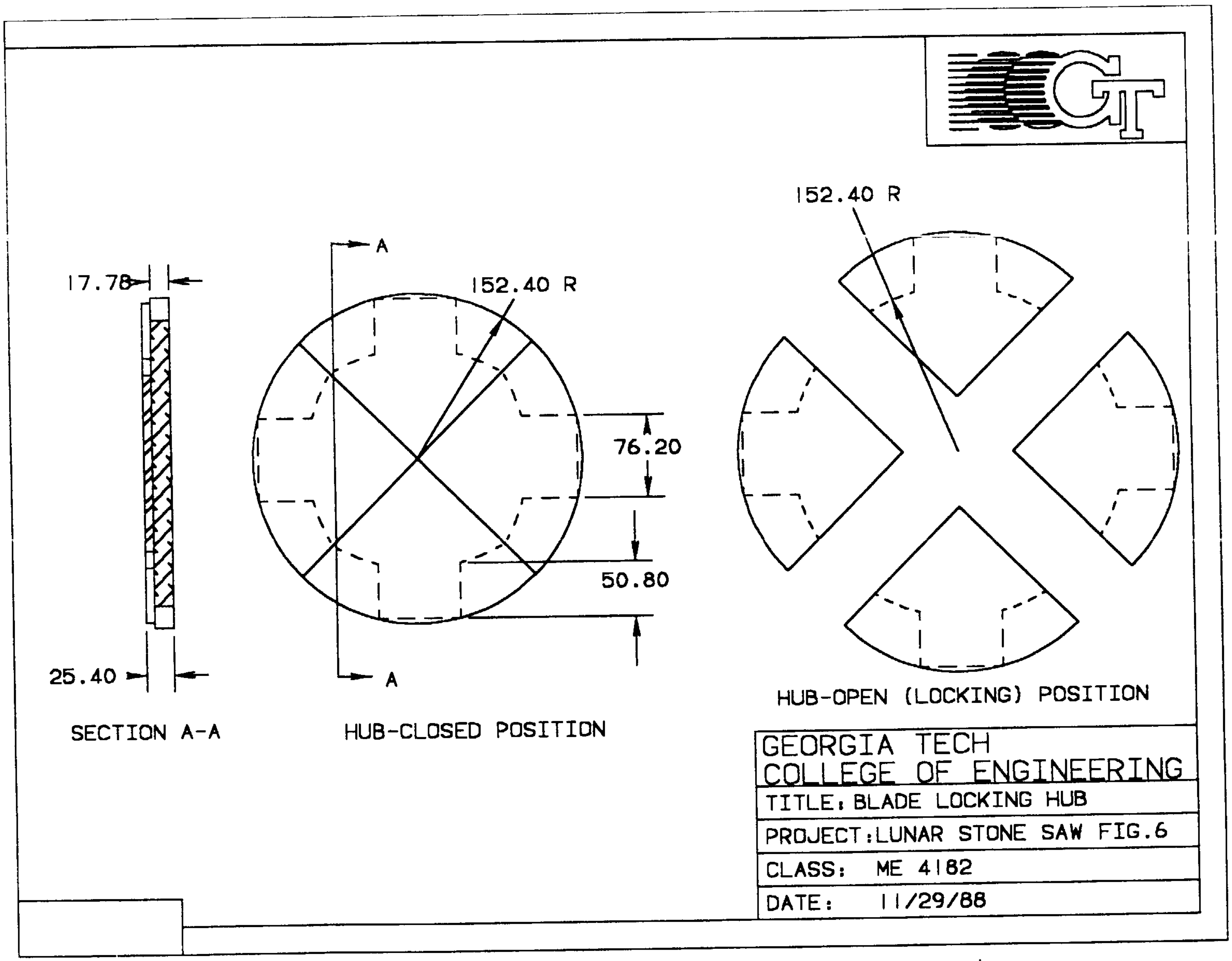
PROJECT: LUNAR STONE SAW FIG.3

CLASS: ME 4182

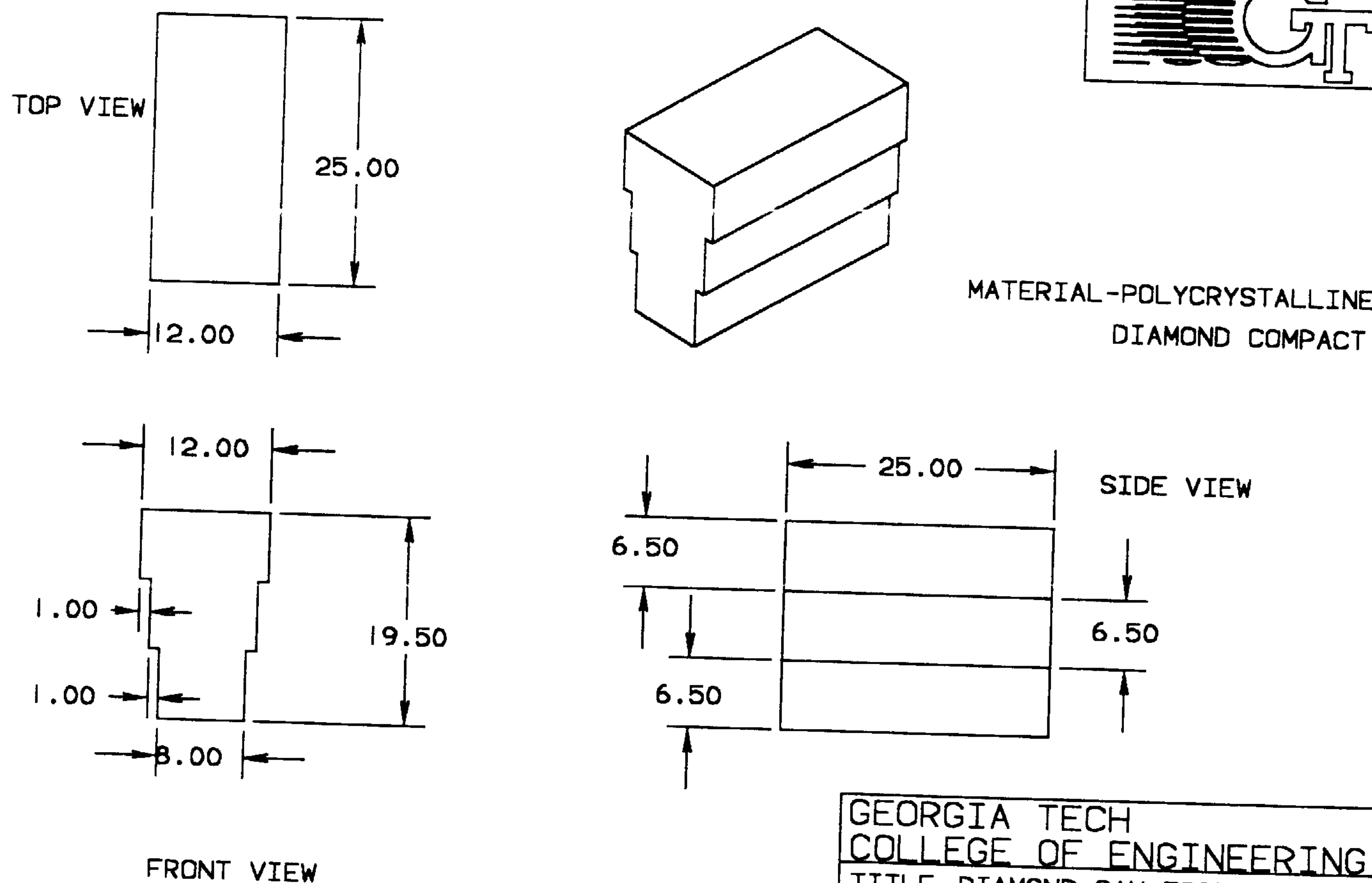
DATE: 11/29/88


RAIL DETAIL
TOP VIEW
TURNTABLE LOCATION
6.5 FEET
5 FEET
BLADE MOTOR
LOCKING HUB
FRONT VIEW
RAILS
BLADE OMITTED FOR CLARITY
SIDE VIEW
PISTON
DEBRIS BROOM
TURNTABLE
SYSTEM POWERED BY HYDRAULIC MOTORS
GEORGIA TECH
COLLEGE OF ENGINEERING
TITLE: LUNAR STONE SAW
PROJECT: LUNAR STONE SAW FIG.4
CLASS: ME 4182
DATE: 11/29/88


SECTION A-A
BLADE MATERIAL- TUNGSTEN AISI T4
HIGH-SPEED STEEL
12.00
19.50
8.00
6.35
TOOTH MATERIAL-POLYCRYSTALLINE
DIAMOND COMPACT
SAW BLADE
A
25.0
25
30.0
15.0 R
A
76.20
52.04
152.40 R
1066.80 R
DETAIL OF EDGE AND TEETH
110 NOTCHES AROUND
BLADE CIRCUMFERENCE
GEORGIA TECH
COLLEGE OF ENGINEERING
TITLE: STONE SAW BLADE
PROJECT: LUNAR STONE SAW FIG.5
CLASS: ME 4182
DATE: 11/29/88
ALL DIMENSIONS IN MILLIMETERS

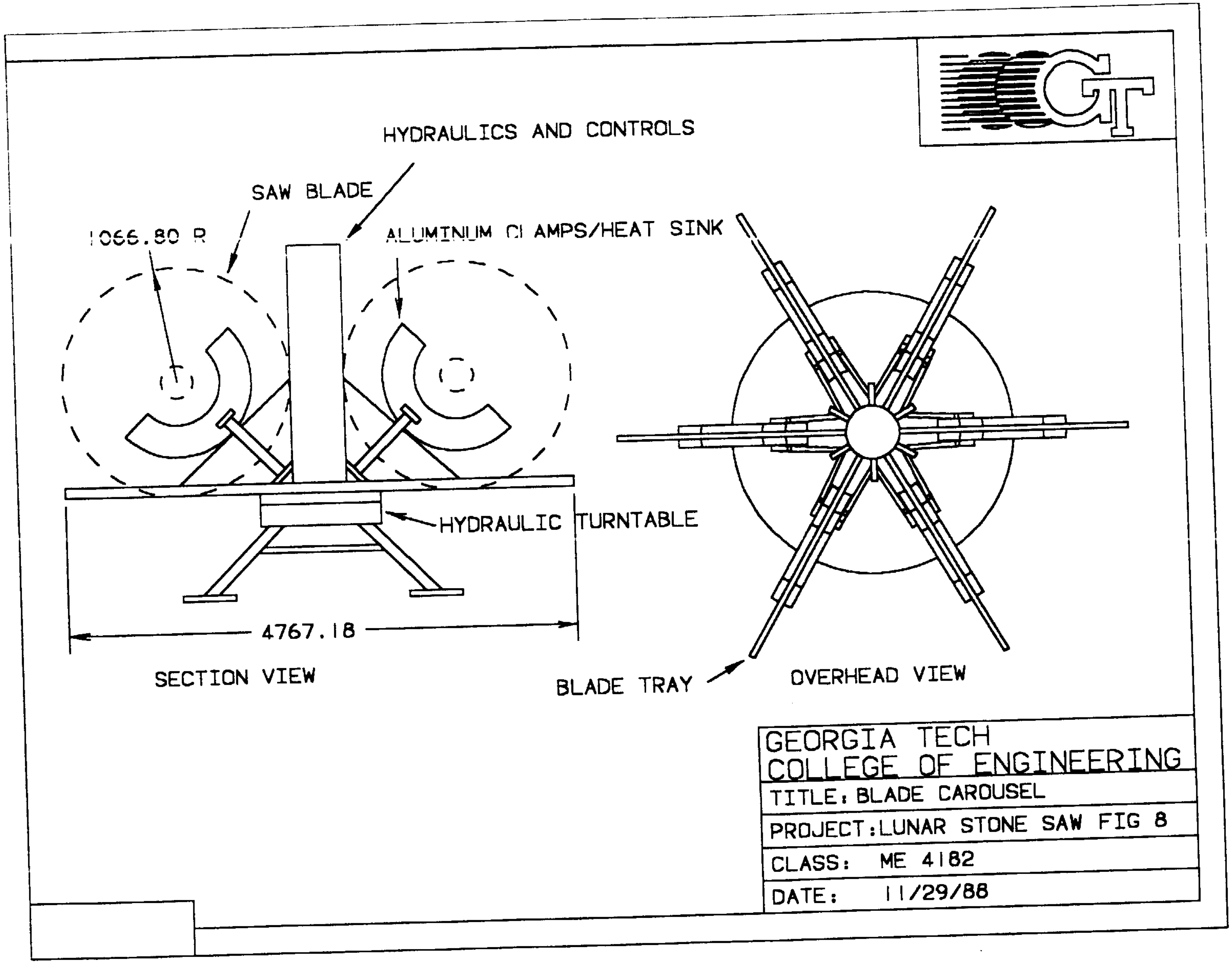


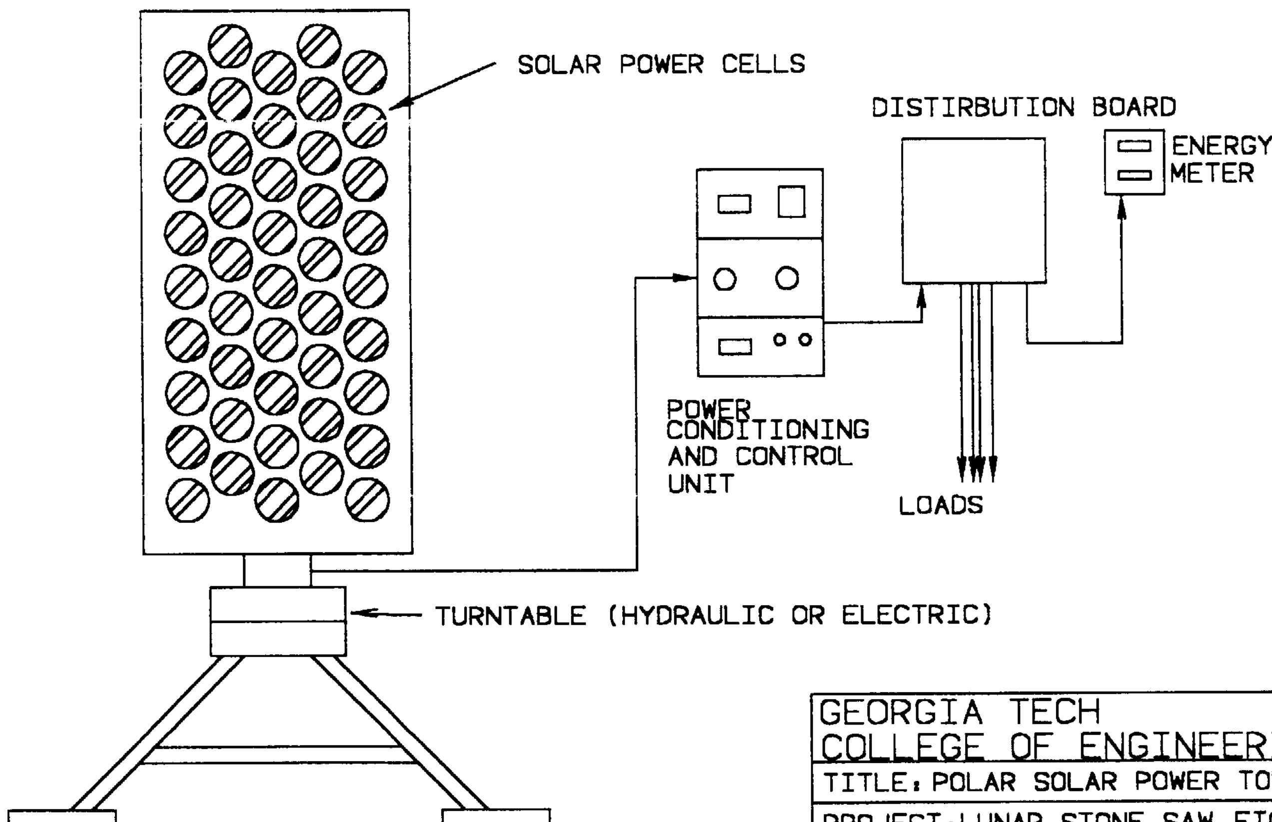
17.78
25.40
SECTION A-A
A
A
152.40 R
76.20
50.80
HUB-CLOSED POSITION
152.40 R
HUB-OPEN (LOCKING) POSITION
GEORGIA TECH
COLLEGE OF ENGINEERING
TITLE: BLADE LOCKING HUB
PROJECT: LUNAR STONE SAW FIG.6
CLASS: ME 4182
DATE: 11/29/88



ALL DIMENSIONS IN MILLIMETERS

GEORGIA TECH COLLEGE OF ENGINEERING
TITLE: DIAMOND SAW TOOTH
PROJECT: LUNAR STONE SAW FIG.7
CLASS: ME 4182
DATE: 11/29/88


HYDRAULICS AND CONTROLS
SAW BLADE
1066.80 R
ALUMINUM CLAMPS/HEAT SINK
HYDRAULIC TURNTABLE
4767.18
SECTION VIEW
BLADE TRAY
OVERHEAD VIEW
GEORGIA TECH
COLLEGE OF ENGINEERING
TITLE: BLADE CAROUSEL
PROJECT: LUNAR STONE SAW FIG 8
CLASS: ME 4182
DATE: 11/29/88



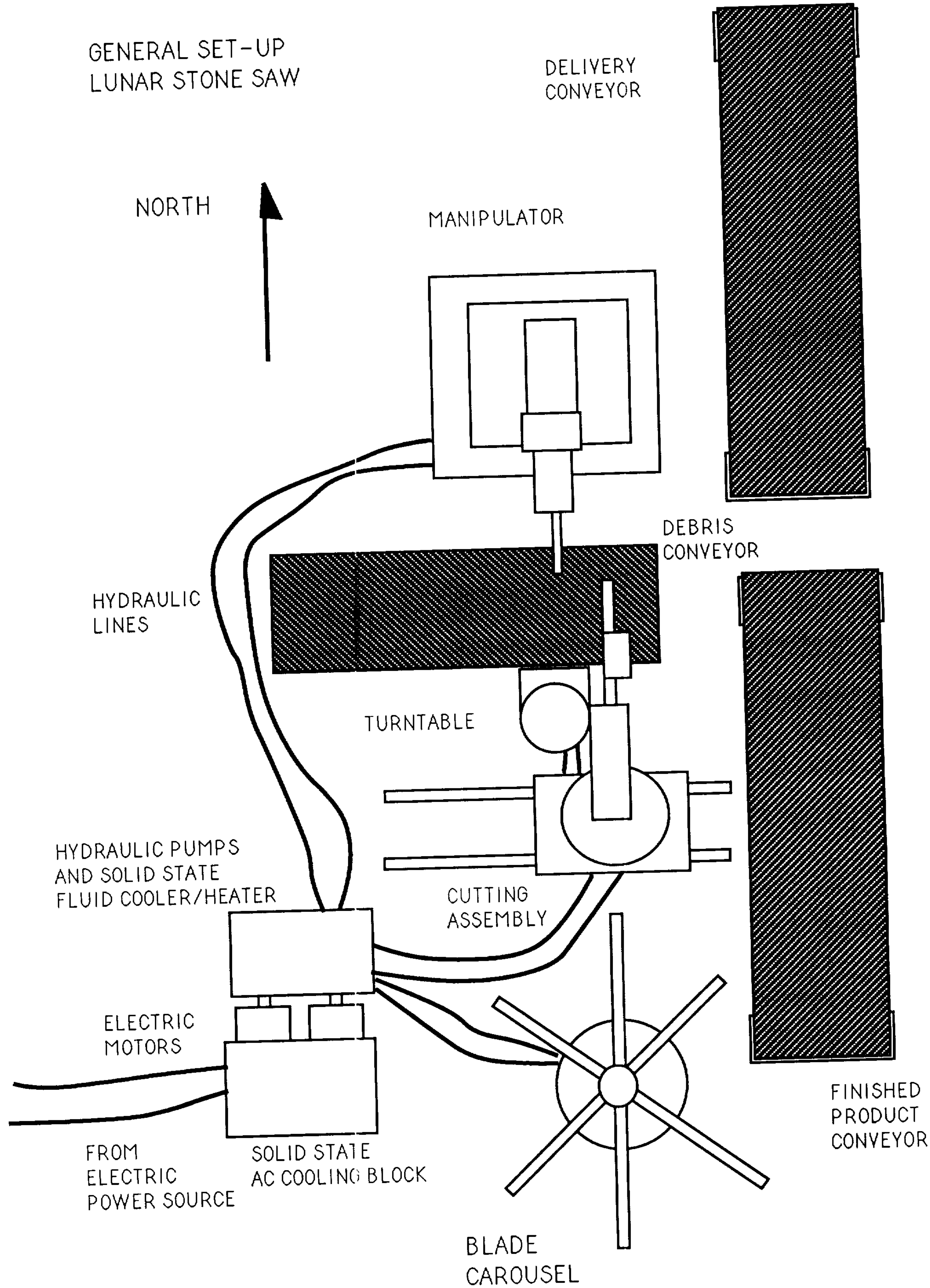
GEORGIA TECH
COLLEGE OF ENGINEERING

TITLE: POLAR SOLAR POWER TOWER

PROJECT: LUNAR STONE SAW FIG. 9

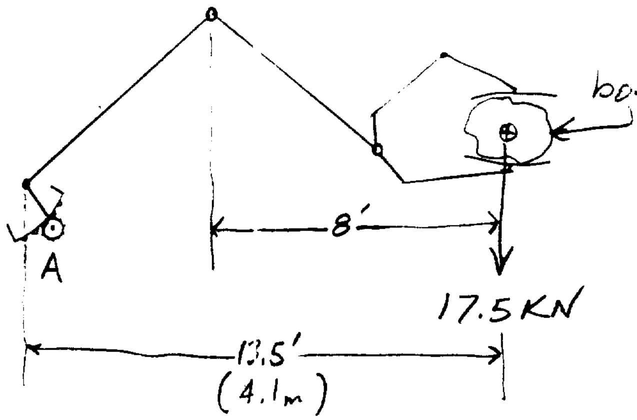
CLASS: ME 4182

DATE: 11/29/88


GENERAL SET-UP
LUNAR STONE SAW
DELIVERY
CONVEYOR
NORTH
MANIPULATOR
DEBRIS
CONVEYOR
HYDRAULIC
LINES
TURNTABLE
HYDRAULIC PUMPS
AND SOLID STATE
FLUID COOLER/HEATER
CUTTING
ASSEMBLY
ELECTRIC
MOTORS
FINISHED
PRODUCT
CONVEYOR
FROM
ELECTRIC
POWER SOURCE
SOLID STATE
AC COOLING BLOCK
BLADE
CAROUSEL

3.13 APPENDIX 1: CALCULATIONS

H.P. Calculation for boulder handler



$\frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(36'' \times \frac{2.54\,cm}{1\,in}\right)^3$
$= 3.2 \times 10^6\ cm^3$

boulder: largest possible =

$3.35\ gm/cm^3 \times 3.2 \times 10^6\ cm^3$
$= 1.072 \times 10^7\ gm$
$= 10{,}720\ kg$

$F = ma$
$= 10{,}720\,kg\,(9.81\ m/s^2) =$
$105{,}163\ N$
$= 105\ KN$

For moon $(\frac{1}{6}g)$
$= 17.5\ KN$

$T = Fd_{\perp}$
$= 17.5\,KN\,(4.1\,m)$
$= 71.75\,KN \cdot m \times \frac{lb}{.225\,N} \times \frac{3.28\,ft}{m}$

Torque at A = 1.05×10^6 lb·ft

$P_A = T_A \omega_A \qquad \omega_A = .5\ \frac{rev}{min} \times \frac{min}{60\ sec} \times \frac{2\pi}{rev} = .053\ \frac{rad}{sec}$

$= (1.05 \times 10^6\ ft\,lb)(.053) = 55{,}650\ \frac{ft\,lbs}{sec} \times \frac{1.341 \times 10^{-3}\ HP}{.73756\ ft\,lb/sec} = 100\ H.P.$

Thus we must deliver ~ 100 HP at A

$P_A = P_{motor}(.85) \Rightarrow$ using 85% as a typical motor/gearbox efficiency

$P_{motor} = \frac{100}{.85} = 120\ H.P.$

Thus we need a 120 H.P. motor

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11/22/88 Ken Hines

Calculations for estimated hydraulic horsepower

	#	H.P.	Psi	in³/rev	Max RPM
Motors for Conveyors :	3	20	5000	~10	~300
SMAU21 Motor for Saw :	1	60	5000	21	480
MH67 Motor for boulder handler :	1	120	3000	67 ~98	300

$\frac{300\,rev}{min}\ \frac{67\,in^3}{rev} \times \frac{ft^3}{1728\,in^3} = 11.63\ ft^3/min \times \frac{1.5859 \times 10^4\ gal/min}{2.1189 \times 10^3\ ft^3/min}$

= 87 gal/min at 3000 psi for MH67

$(300)(10)\left(\frac{1}{1728}\right)\left(\frac{1.5859 \times 10^4}{2.1189 \times 10^3}\right) = 13$ gal/min at 5000 psi for 10 H.P. motor

$480(21)\left(\frac{1}{1728}\right)\left(\frac{1.5859 \times 10^4}{2.1189 \times 10^3}\right) = 44$ gal/min at 5000 psi for SMAU 21

Total GPM for Plant

3 (13 GPM) + 44 GPM = 83 GPM at 5000 psi
87 GPM at 3000 psi

Now we can estimate the H.P. required using the relations:

$hp|_{hydraulic} = \frac{P(psi) \times Q(gpm)}{1714}$ and due to mechanical losses: $H.P. = hp|_{hydraulic} + 20\%$

$hp = \frac{(3000\ psi)(87\ GPM)}{1714} = 152$

$H.P. = 152 + 152(.2) = 182$

H.P. ≃ 200 for the 5000 psi pump

$hp = \frac{(5000\ psi)(83\ GPM)}{1714} = 242$

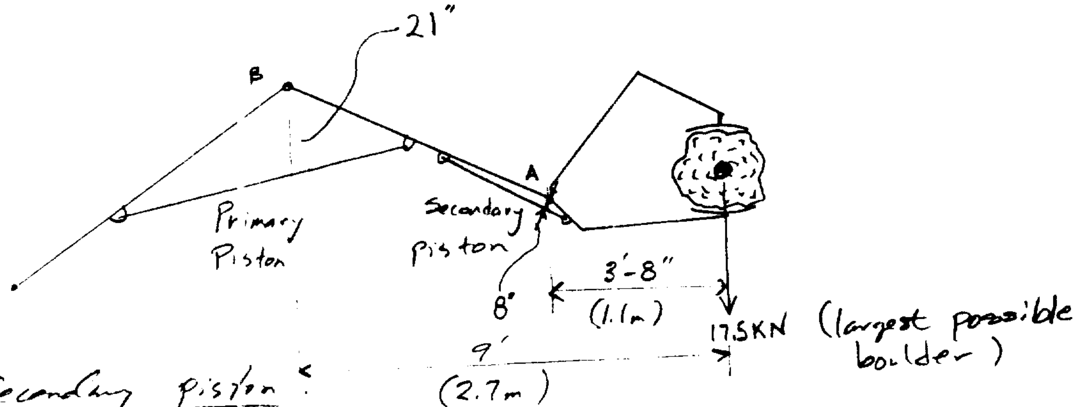
$Hp = 242 + 242(.2) = 290$

H.P. = 300 for the 5000 psi pump

11/26/88 [illegible]

Static Calculations for boulder handler scale = 1/4"

$44" \times \frac{2.54 cm}{1 in} = 1.1 m$



For Secondary piston:

Torques must be equal around A:

$F_{piston}(8") = 17.5KN(44")$

$F_{piston} = 96.3 KN$

$= 21,656\ lb_f$

$3000\ psi = \frac{21656\ lb}{x}$ $x = 7.22\ in^2$

Piston bore $\geq 7.22\ in^2 = \pi r^2$
diameter ≥ 3.03 inches

For Primary Piston:

Torques must be equal around B:

$F_{piston}(21") = 17.5KN(108")$

$F_{piston} = 90 KN$

$= 20,250\ lb_f$

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Blade Calculations:

Radius = 1.067 meters

Area = 3.58 m^2

Thickness = $.25 \text{ in} \frac{1 \text{ ft}}{12 \text{ in}} \frac{.3048 \text{ m}}{1 \text{ ft}}$ = .000635 m

Volume = .00227 m^3

Weight = $(8.68 \frac{\text{Mg}}{m^3})(.00227 \, m^3)$ = .01973 Mg

$$\left(150 \frac{\text{rev}}{\text{min}}\right)\left(\frac{2\pi \text{ rad}}{1 \text{ rev}}\right)\left(\frac{1 \text{ min}}{60 \text{ sec}}\right) = 15.7 \frac{\text{rad}}{\text{s}}$$

Speed at outer edge of blade = $(15.7 \frac{\text{rad}}{\text{s}})(1.067 \text{ m})$

= 16.76 m/s

Radiation Heat Transfer

Perfect radiator → $q_r = \sigma A T^4$

Emissivity of T4 = .80

Radiation at 1000° F = $(5.67 \times 10^{-8})(3.58)(811)^4(.8)$

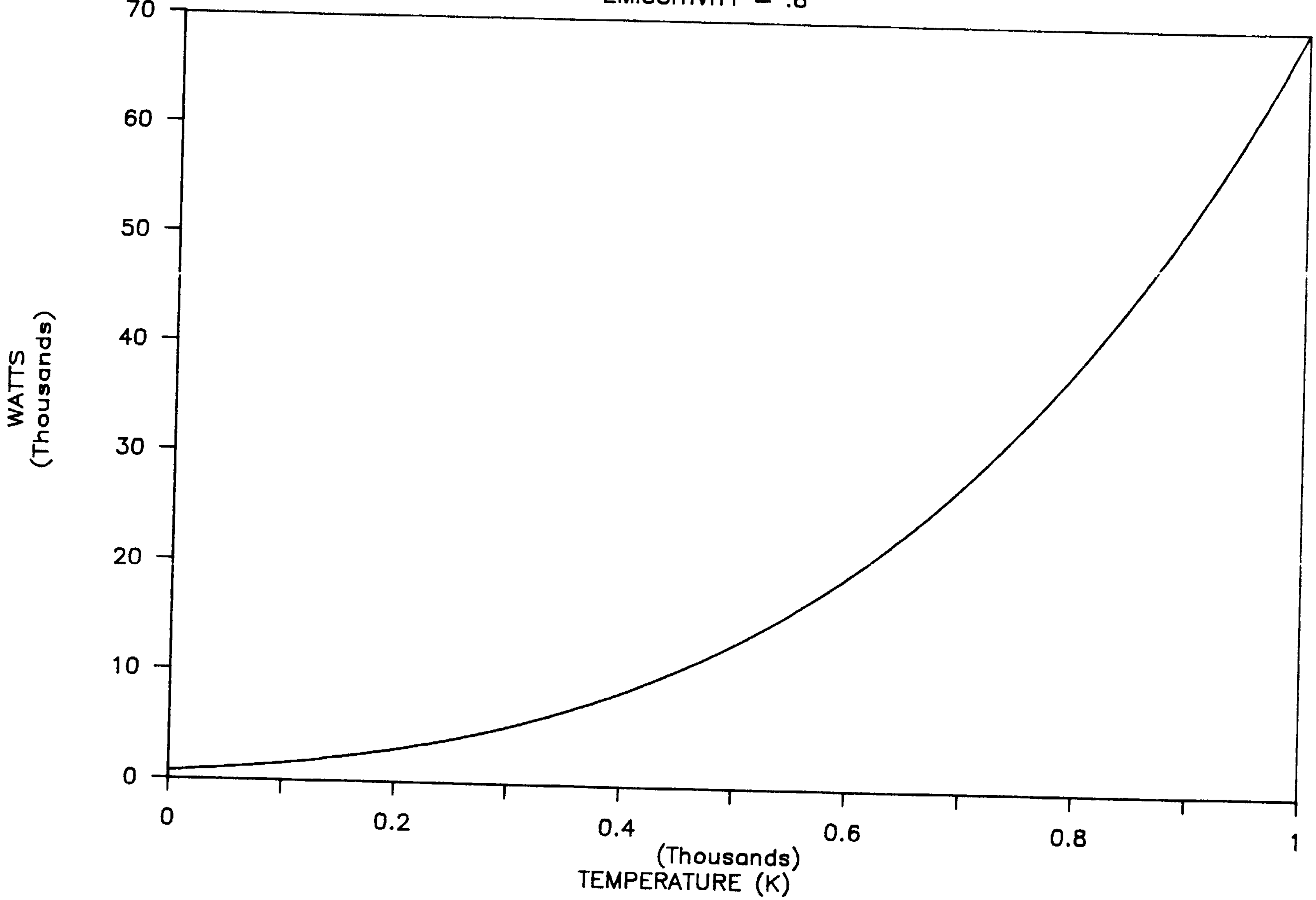
= 70,171 Watts

See next page for radiations over large temperature range.

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RADIATION TO BLACKBODY (SPACE)

EMISSIVITY = .8



Solar Power Calculations:

$1 \text{ Hp} = 746 \text{ watts}$

Power of Pumping Motors: $P_{pump} = (500 \text{Hp})\left(746 \frac{\text{watts}}{\text{Hp}}\right)\left(\frac{1 \text{Kw}}{1000 \text{w}}\right)$

$P_{pump} = 373 \text{ Kw}$

System inefficiencies: $P_{ineff.} = .20 \times P_{pump}$

$P_{ineff.} = 74.6 \text{ Kw}$

Power for lights, etc.: $P_{aux.} = P_{TOTAL} - P_{pump} - P_{ineff}$

$= 500 \text{Kw} - 373 \text{Kw} - 74.6 \text{Kw}$

$P_{aux.} = 52.4 \text{ Kw}$

Power loss in event of sub-array failure: $\% \text{loss} = \left(\frac{P_{one\ array}}{P_{TOT}}\right) \times 100$

$= \left(\frac{25 \text{Kw}}{500 \text{Kw}}\right) \times 100$

$\% \text{loss} = 5\%$

3.14 APPENDIX 2: ALTERNATIVES

ALTERNATIVES FOR SAW

Four types of design were considered for the saw. Design I consisted of a band saw. Although this type of saw was the best for cutting curved shapes, it was felt that the small, thin blade would not be able to conduct the heat well enough to prevent melting. Also, this blade would be much harder to change. For these reasons design II was looked into. This design consisted of a circular saw under a table which could move back and fourth. Since only straight cuts can be made with a circular saw blade, this design required the blocks to be of simple geometry. This is the reason the building consists only of rectangular blocks.

Problems developed when it came time to determine how to cool and change this blade. Since the blade is within a table, it would be quite difficult to remotely change the blade (as well as very time consuming). Also, the mechanical complexity of this table would be very high due to the fact that the table would have to handle the boulder quite a few times to get the required cuts.

Design III consisted of a laser manipulated by an industrial robot. This design has many advantages since it could cut any shape, cut in any direction, and would need very little cooling. However, it was found that the laser simply required more power than the solar cells could deliver.

Like the vast majority of engineering solutions, the answer was found by combining several solutions into one. Design IV is just such a combination of designs II and III in which a circular blade is manipulated by a robot arm. Many robots of this type and size are in use so most problems associated with it have been solved. This design offers ease of blade changing and low power consumption. See design matrix in Appendix 2 for a comparison.

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	EASE OF COOLING (4)	EASE OF CHANGING BLADE (2)	POWER REQUIRED (3)	MECHANICAL COMPLEXITY (1)
DESIGN I BAND SAW	1	1	4	2
DESIGN II TABLE SAW	2	1	4	2
DESIGN III LASER	4	4	1	4
DESIGN IV ROBOT SAW	3	4	4	3

1 WORST → 4 BEST

DESIGN I = 20 pts DESIGN II = 24 pts DESIGN III = 31 DESIGN IV = 35 BEST

ALTERNATIVES FOR POWER SUPPLY

1. Since all cutting must be done in the dark, one alternative solution could be the introduction of a battery storage facility into the electrical system. Charging of the system would occur during the lunar day and the cutting sequence would occur during the lunar night from the battery storage. However, this alternative was discarded since the plant was moved to a crater.

One problem that may arise from this technique is that no solar battery system of the present is able to run a system of this size for the length of time required (1 lunar day). Once technology finds a storage system able to meet these output and time duration requirements, this alternative could become a practical solution to the prescribed problem. This idea, however, was dropped when it was decided to locate the plant in the crater

2. Another possible solution would be to cover the saw with a device that protects the saw from the intense solar radiation. This solution would allow the cutting process to be done during the day. No battery storage would be necessary in this case.

One problem that would arise from enclosing the area around the saw is that a cloud of dust from the saw would be concentrated around the saw. The lunar dust is very abrasive and would cause severe damage to the moving parts. The dust is already a problem with no covering present, however, the addition of a cover would immensely speed up the rate at which damage is done to the saw.

3. A final alternative investigated was to put solar collector towers at the south pole of the moon and run cable to the plant site. The most desired site for the plant would be at the equator due to the least amount of energy required to land there. However, this location would require cable approximately 1000 to 1500 miles in length (approximately 1/4 the circumference of the moon).

Problems arise from the amount of cable required to carry the large amount of power such a long distance. Extremely high cost in the manufacturing and transporting of the cable would make this alternative obsolete. In addition, huge losses in power from such a long distance between the solar tower and the cutting plant would be hard to overcome.

SAW BLADE

Once we decided on using a circular saw to cut the stone, the design of the blade itself was fixed. The shape of both the blade and diamond segments are proven designs. This design is now used to cut various kinds of stone with blades both larger and smaller than our own. We did need to make our blade from a better material to accommodate the high operating temperatures. Within the high speed tool steel category there are approximately 80 different materials. Our design choice matrix is given on the next page. From this matrix, with hot hardness and wear resistance being the two crucial properties, we determined Tungsten AISI T4 to be the best metal for our purposes.

Tool Steel Decision Matrix

Scale 1(low) ↔ 5(High)	Hot Hardness X 10	Wear Resistance X 8	HRC X 4	Machinability X 4	Resistance to softening X 4	Totals
Molybdenum	4	4	5	2	4	116
Tungsten	5	4	4	2	4	122
Chromium	3	3	1	3	4	86
Shock resisting	1	2	2	3	2	54
Low Carbon	2	2	3	3	2	68

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Factors / Solutions	Amount of Stone Required	Size of Block Required (Smaller usually Better)	Complexity of block Shape	Structural Rigidity	Ease of Construction	Time Required for job	Cost of cutting Equipment	Complexity of actual Cutting Procedure	Total
Ranking -	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	2	
Igloo	1	1	1	5	1	1	1	1	47
Dome	1	1	1	3	1	1	1	1	37
Equilateral Arch	3	5	5	4	5	5	5	5	124
Semi-Circular Arch	4	4	2	3	3	2	2	4	79
Cubic Building (4 walls & Roof)	5	4	5	1	2	4	5	4	94
Trench w/ roof	4	2	4	1	2	3	4	3	73

DECISION MATRIX FOR TRANSPORT SYSTEM

	ACCURACY	REPAIRABILITY	DEPENDABILITY	FEASABILITY	SIMPLICITY	TOTALS
CONVEYOR	5	4	5	5	4	23
TRAJECTORY	2	4	4	3	4	17
ROVERS	5	3	2	3	1	14
MOBILIZING SAW	5	4	5	3	2	19

∴ CONVEYOR IS BEST DESIGN

3.15 APPENDIX 3: PROGRESS REPORTS

Project Name: Lunar Stone Saw

Date: 10-03-88

During the last week, we decided on the basic architectural design of the lunar buildings that are to be constructed from the stones cut by the lunar saw. These buildings will be semicircular in cross-section and approximately 60 ft. in length.

With the design of the structure decided upon, we began to discuss some design characteristics for the saws and rock gathering techniques. Some of those characteristics are as follows:

-- Stone "factory" must be transportable to be able to move to areas where the raw stones are available

-- Rock gathering system must be able to measure size of rocks

-- Saw blades must have a very long life

-- Entire system must be as "maintenance free" as possible

-- Must use solar/battery power

-- Lubrication system must be able to survive in a vacuum

Tom Clark
Todd Croker
Ken Hines
Mike Knight
Todd Walton

Project Name: Lunar Stone Saw

Date: 10-11-88

During the past week, the group decided on the final shape and design of a lunar building. It was determined that an arch made out of brick shaped rocks would yield a successful building design. To insure that the design would not collapse, several goup members made a model out of bricks. The model did not collapse; it proved to be very sturdy. Furthermore, research turned up a lunar adhesive which could be used to further increase the safety of the building.

Heat transfer schemes were also devised in the past week. It was determined that a high temperature steel blade would be used as a cutting device. This steel would be coated with some material which has a high emissivity. This would increase the radiative heat transfer from the blade.

A flow chart was also drawn up. The flow chart outlines the procedure that would be used to collect and cut the lunar boulders. This chart allowed us to target our project and analyze exactly what we needed to design.

Tom Clark

Todd Croker

Ken Hines

Mike Knight

Todd Walton

LUNAR STONE SAW

ME4182 Fall Quarter, 1988

Professor: Mr. J.W. Brazell

Our group accomplished many things this week and we hope to be through with the research aspect of this project by Friday October 21, 1988. At that time we will start the actual hard copy design of our lunar stone saw. For the past week each group member researched his own particular subject pertaining to this project. Tom Clark has been looking into the possibility of producing some type of "mortar" which can be manufactured and used on the lunar surface for our purposes. Tom has found a way to make a type of cement out of melted sulfur. He is now researching this process further. Todd Crcker has been researching the material from which to make our cutting blade. After talking to Dr. McDowell and Dr. Meyers Todd is now looking at a diamond tipped blade made from a high temperature, high speed tool steal. At the present time we are leaning towards the 630(M1) steel. Ken Hines has been organizing our data search. Ken has determined what item we want the library to search for through their data bases. Ken is also trying to determine the maximum temperature our saw blade will obtain. Mike Knight has been researching and designing our structural design. Mike has looked into many different types of structures and has now settled on one design. At the present time Mike is building and drawing scaled replicas of the

design which he has chosen. Todd Walton is researching a material which has a high emissivity which can be used to coat our saw blade. Todd is also trying to determine an actual production rate for large scale stone cutting. Todd plans a trip to a rock quarry such as Vulcan Materials to help determine this production rate. These are the activities of Team 2 as of October 17, 1988.

M.T. Walton

M.D. Knight

K.M. Hines

T.P. Croker

T.W. Clark

Project Name: Lunar Stone Saw

Date: 10-25-88

During the past week, the group worked on the outline for the oral presentation that is due on Thursday (10-27). In the outline the problem statement was narrowed down more specifically, the progress thus far made was reviewed and summarized, the information sources were listed, and an outline of future plans was laid.

Information sources were divided up between members of the group in an effort to contact as many sources as possible. Some of the intended sources were: Bureau of Mines , GE-VSMF, Lunar and Planetary Database, Fastener group, and NASA. Some of the informational sources from the database search were accumulated and divided up between members of the group.

Plans were made for several members of the group to visit a quarry north of Atlanta to observe cutting methods and to gather information on production output. In addition,the trip will hopefully show details in the cutting procedure that may have been overlooked thus far.

Project Name:Lunar Stone Saw

Date: 11/1/88

The vast majority of our time this week was spent preparing for the oral progress report. Also, Tom Clark spent time training on how to make CAD drawings (see attached drawing).

Ken Hines met with Martha Griffin of the Ga. Tech library to discuss the database search. He also contacted the 4182 group working on fastners to inform them that we would like to see their ideas on the fastners we could use for the saw and saw blade. They will contact when this information becomes available.

Todd Walton visited a local quarry and was able to get some valuable information from them concerning output rate and saw motor horsepower required (about 30 H.P.).

Finally, Mike Knight contacted a NASA engineer about getting us some information on lubrication and heat transfer in a vacuum. Hopefully, he will get back to us through Jill within the week.

Tom Clark

Todd Croker

Ken Hines

Mike Knight

Todd Walton

ME 4182 MECHANICAL ENGINEERING DESIGN
Fall Quarter 1988
Professor: Mr. J. W. Brazell

LUNAR BOULDER RECONFIGURATION PROJECT

Progress Report: November7, 1988

The major accomplishment this week was the division of labor for the final project stages:

Mike Knight - Power systems
Todd Croker - Blade design
Todd Walton - Conveyor design
Ken Hines - Design integration
Thomas Clark - Draftsman and integration

Most of the data base search results also arrived this week. The most promising information concerns a magazine called the Industrial Diamond Review. Luckily the Georgia Tech Library carries this journal so that is easily accessible.

Todd Croker has gotten in touch with the New England Diamond Company but has not yet talked to the company's vice-president. Todd Walton is trying to get in touch with the Georgia Bureau of Mines. Tom Clark has been assigned the job of getting touch with the Lunar and Planetary Database and NASA.

A CADAM account has also been set up for our use by Doug Smith, the CAD user assistant on the second floor of the French building.

Tom Clark
Todd Croker
Ken Hines
Mike Knight
Todd Walton

The past week incorporated breaking the design into five major parts and distributing them to individuals within the group. These five groups are as follows.

Blade Design - Todd Croker
Power Supply - Mike Knight
Saw Design - Ken Hines
Conveyor Design - Todd Walton
CAD -Tom Clark

Each person is responsible for submitting a detailed sketch of their respective part to Tom on Wednesday, November 16 in order for CAD drawings to be made.

Articles that were found through the database search were also distributed equally among the the members. Each person is responsible for researching their individual articles and reporting their findings to the group. Other resources have been researched as well. These include the Bureau of Mines, the Georgia Mining Association, and vendor literature. The vendor literature turned up a material, silicon, from which the solar panels could be made. The Georgia Mining Association is also putting together a package on mining technology.

The rest of the work that has been done in the past week is individual design work. Sketches have been drawn, redesigned, and redrawn.

Tom Clark
Todd Croker
Ken Hines
Mike Knight
Todd Walton

Weekly Report for the Week of 11/21/88

Group: Lunar Stone Saw

This week was spent preparing the rough draft report to be reviewed by Professor Brazell. Many design changes were also made. These changes include:

*Moved entire operation to a location near the lunar pole. This was done to help with heat buildup from direct solar radiation. Before, we had planned to protect the plant with solar panels as a means of reducing exposure but the NASA engineer Jill contacted for us rejected this idea due to the dust buildup it would cause. This left us with the choice of operating only at night with electric power coming all the way form the other side of the moon or moving to a location that was never exposed to light but also near an area where our solar tower would always be in light. Using batteries was ruled out because of their limited power.

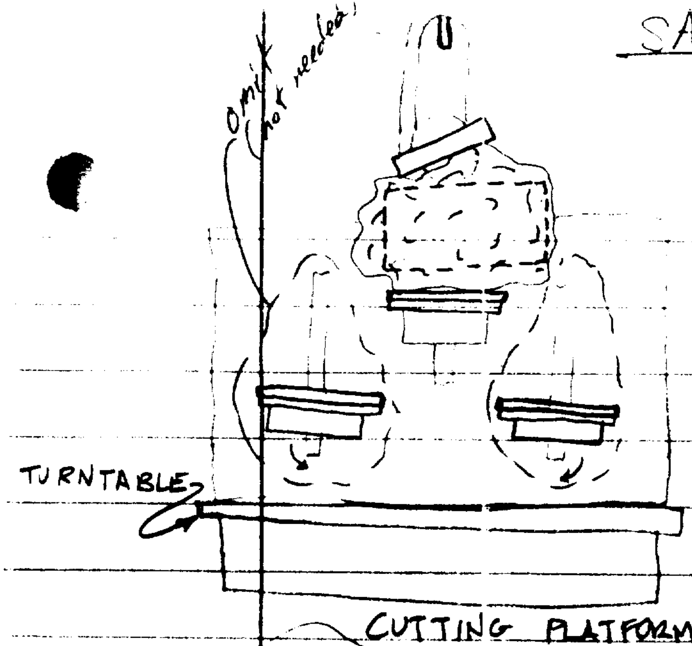
*Due to the lack of developed electric motors with sufficient horsepower that can operate in a vacuum, we changed over to lighter hydraulic motors for all purposes except for the two motors used to generate the hydraulic pressure to run everything.

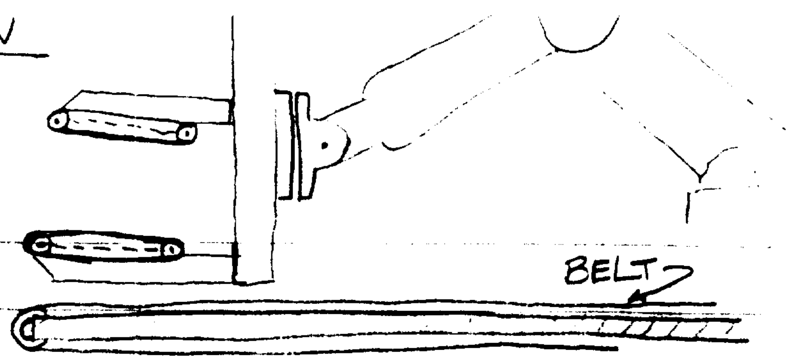
Also, Tom Clark started work on the CAD drawings that have been given to him so far (see attached).

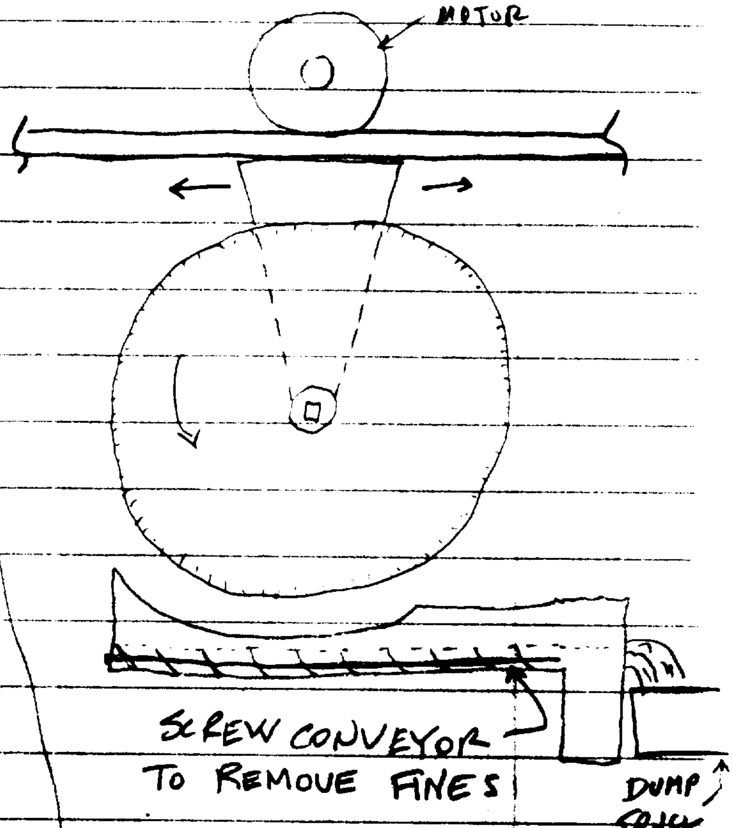
Ken Hines
Todd Croker
Todd Walton
Mike Knight
Tom Clark

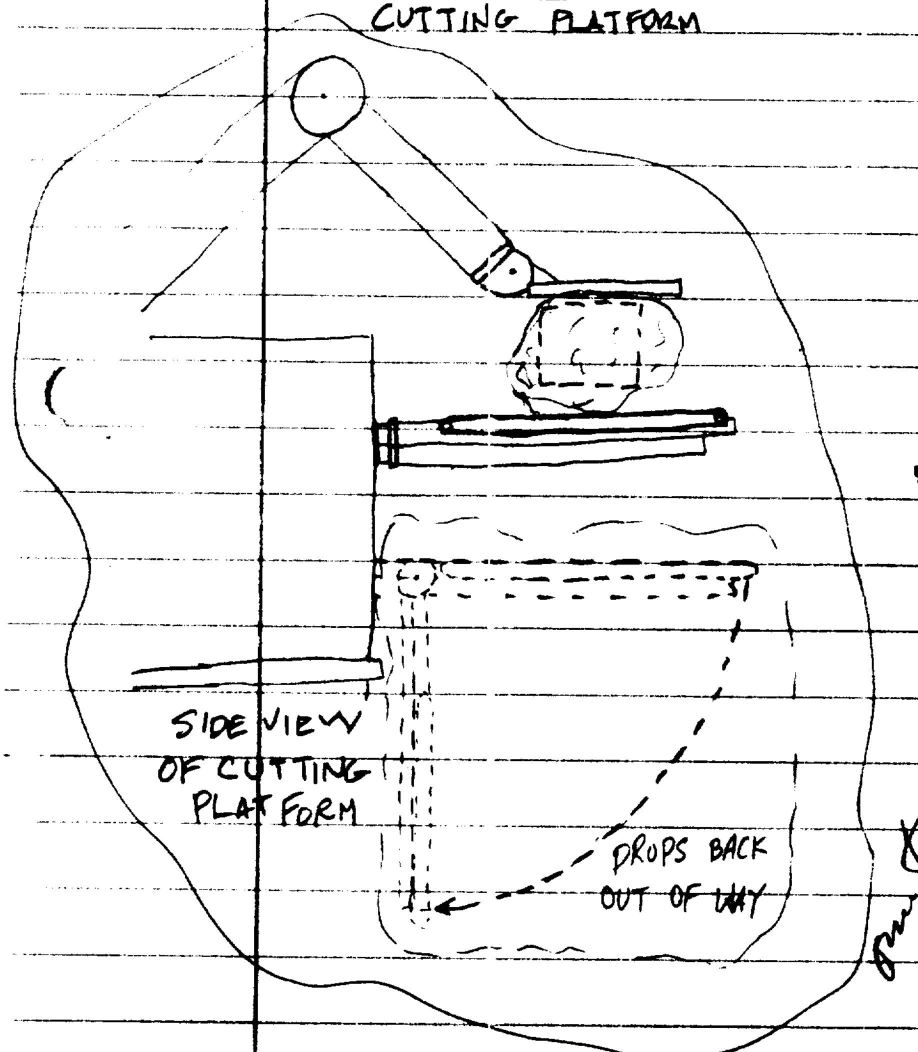
3.16 APPENDIX 4: PRELIMINARY DESIGNS

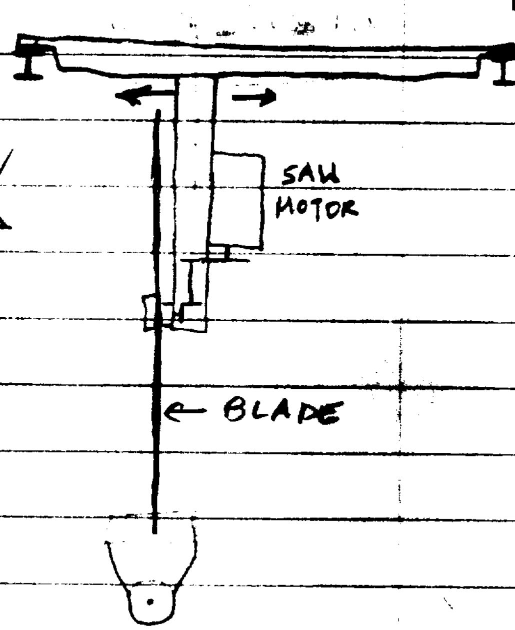
SAW


omit (not needed)
TURNTABLE
CUTTING PLATFORM

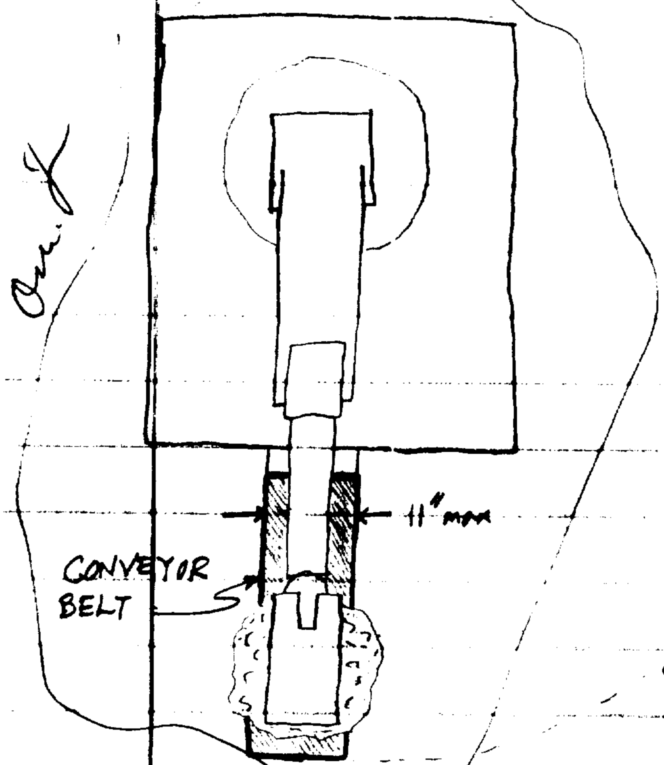

BELT

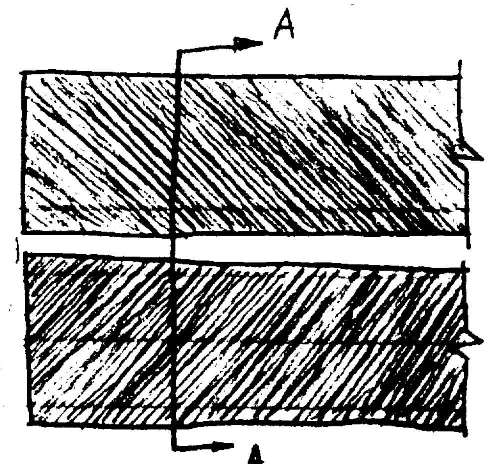

MOTOR
SCREW CONVEYOR
TO REMOVE FINES
DUMP TRUCK


SIDE VIEW
OF CUTTING
PLATFORM
DROPS BACK
OUT OF WAY

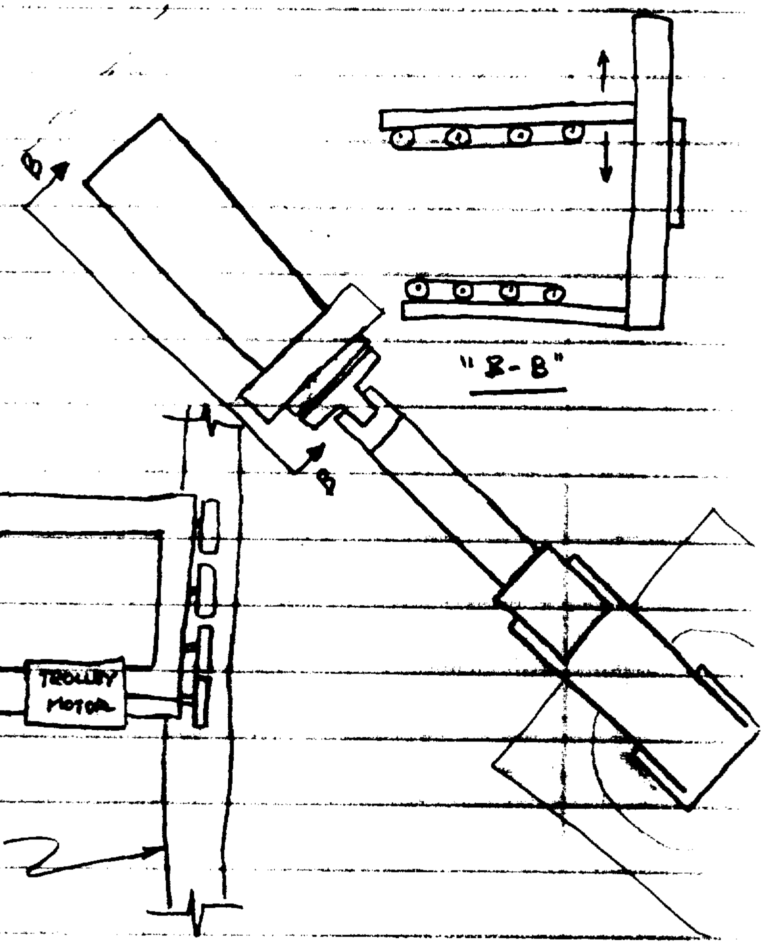

SAW
MOTOR
BLADE

"A-A"



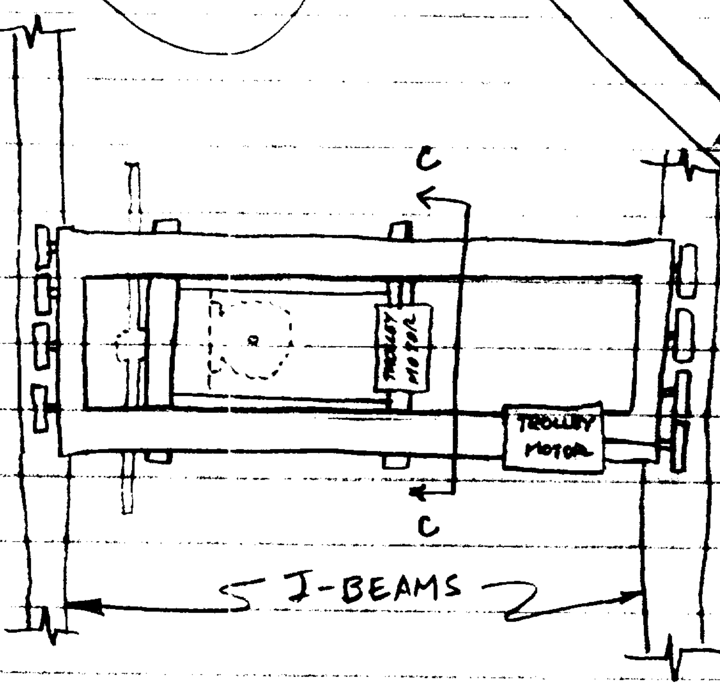


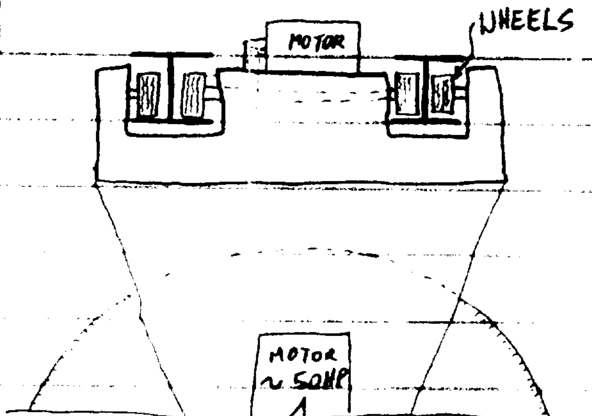
DELIVARY CONVEYORS



"B-B"

Saw on robotic Arm





Grip once – set down only to regrip

Make diagram of tasks / machines

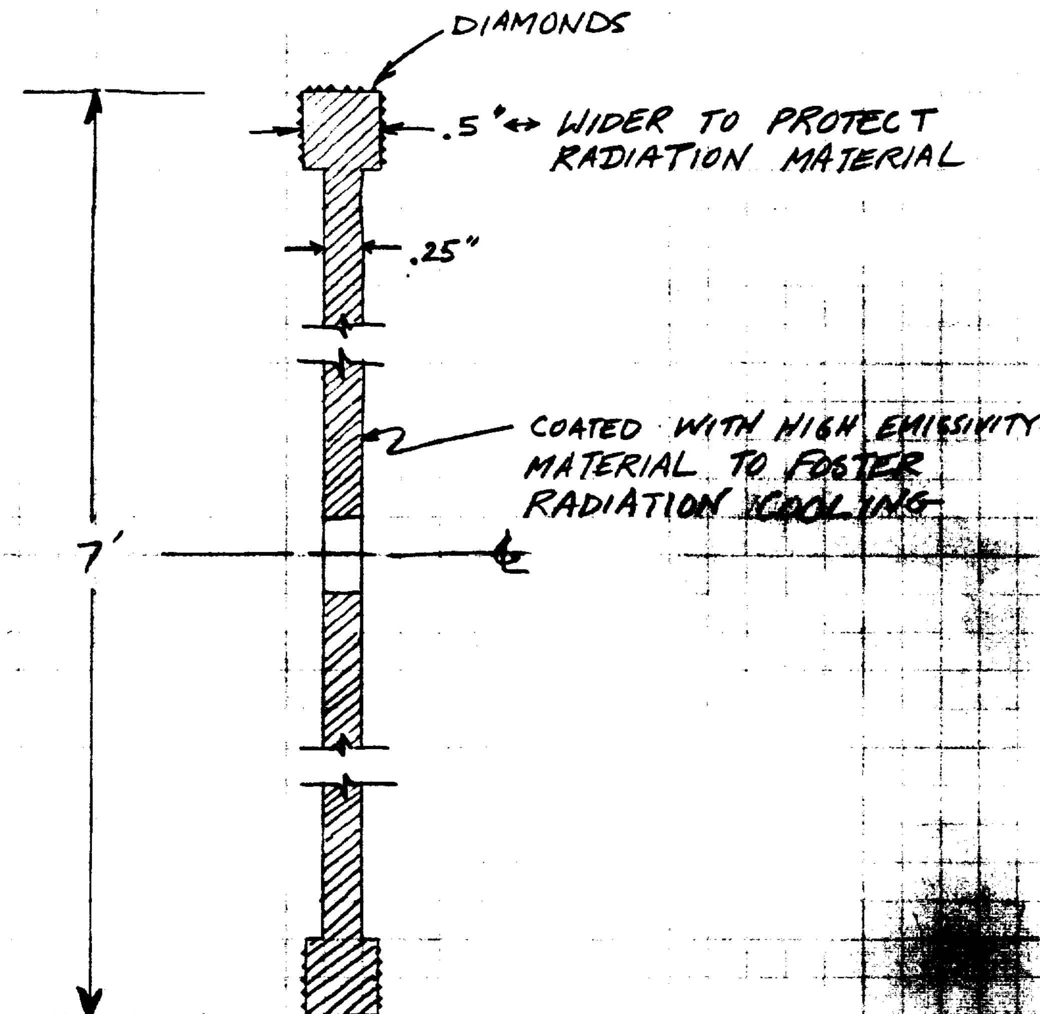
PRELIMINARY BLADE DESIGN

MATERIAL: HIGH TEMPERATURE STEEL

COOLING: RADIATION

DIMENSIONS: DIAMETER: 7' (GIVES ~ 3' CUTTING DEPTH)
THICKNESS: .25"–.5"

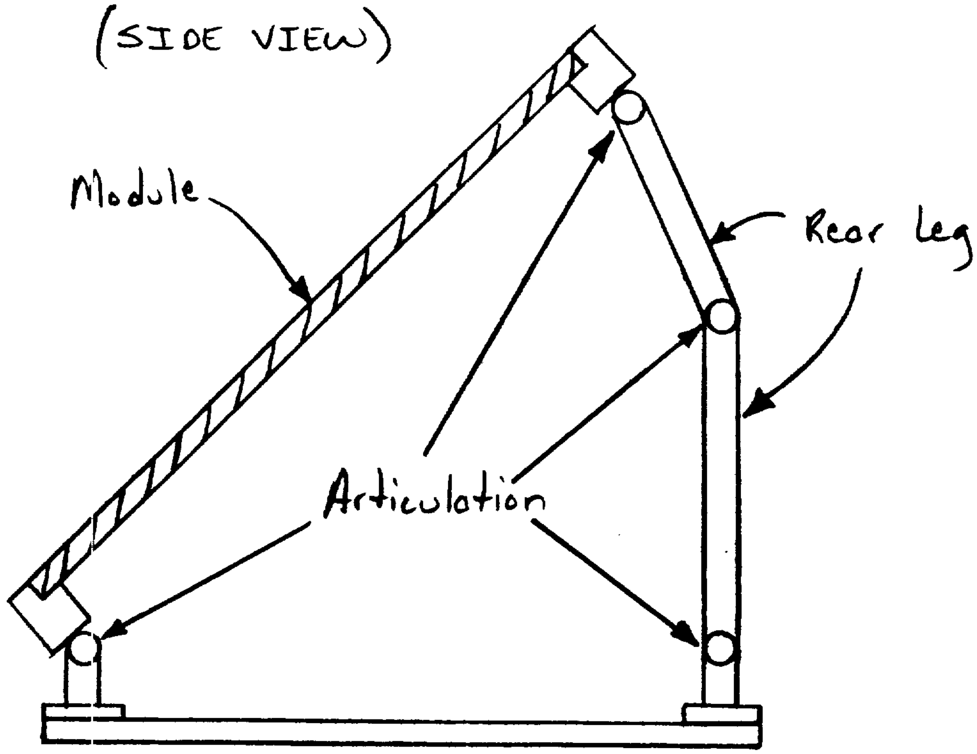
CUTTING MEDIUM: DIAMOND



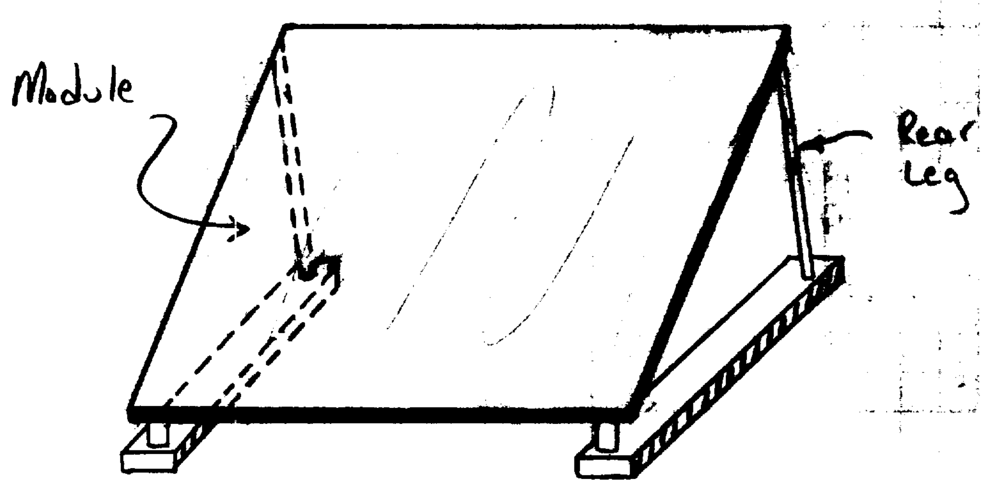
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Module Support Structure

(SIDE VIEW)

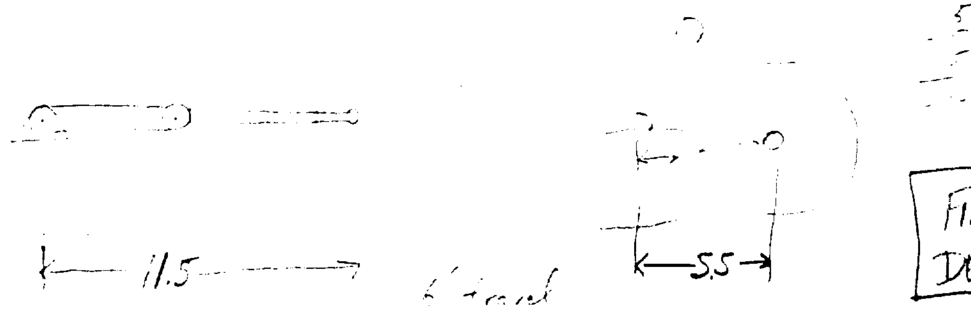


(FRONT VIEW)

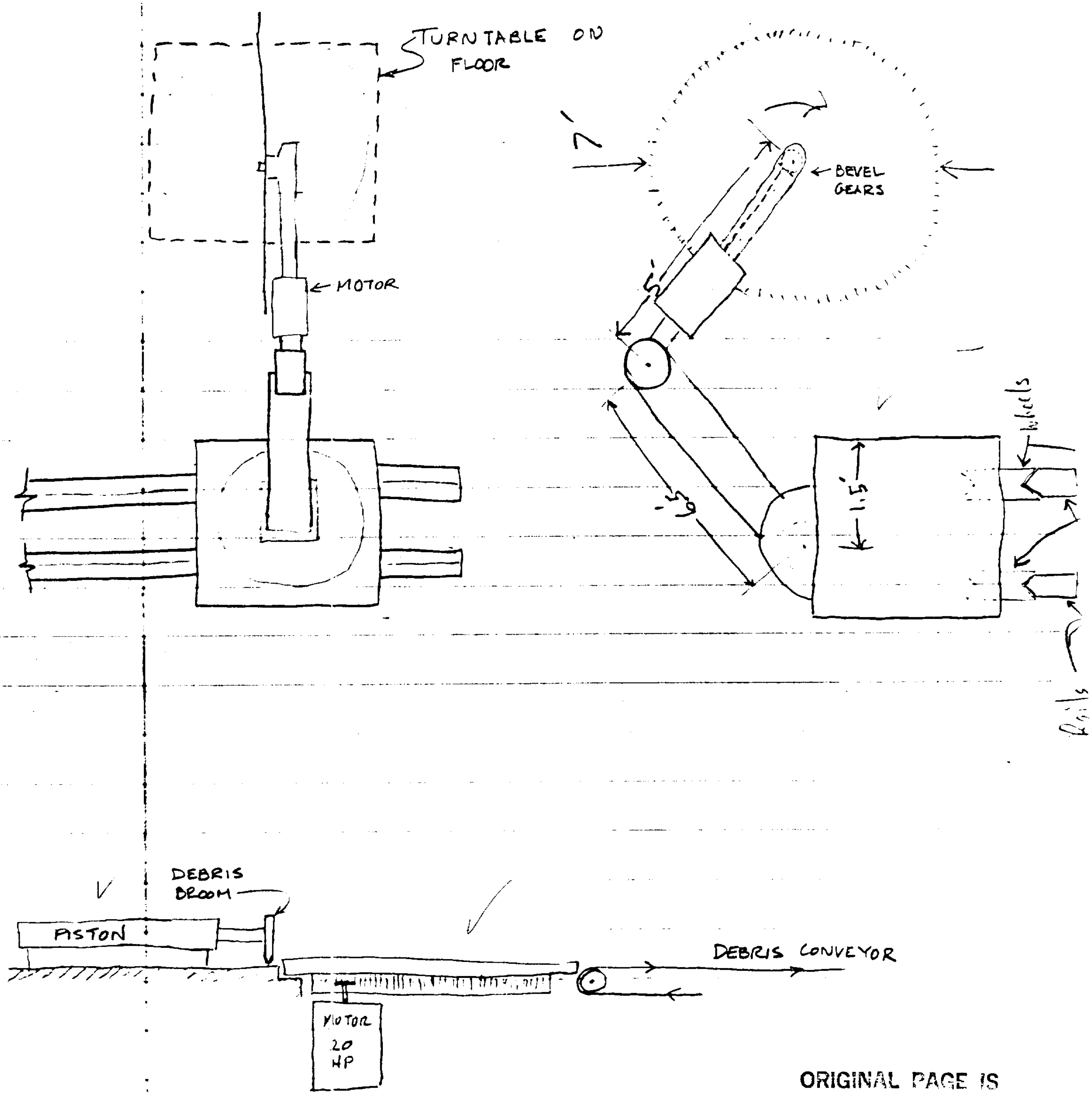


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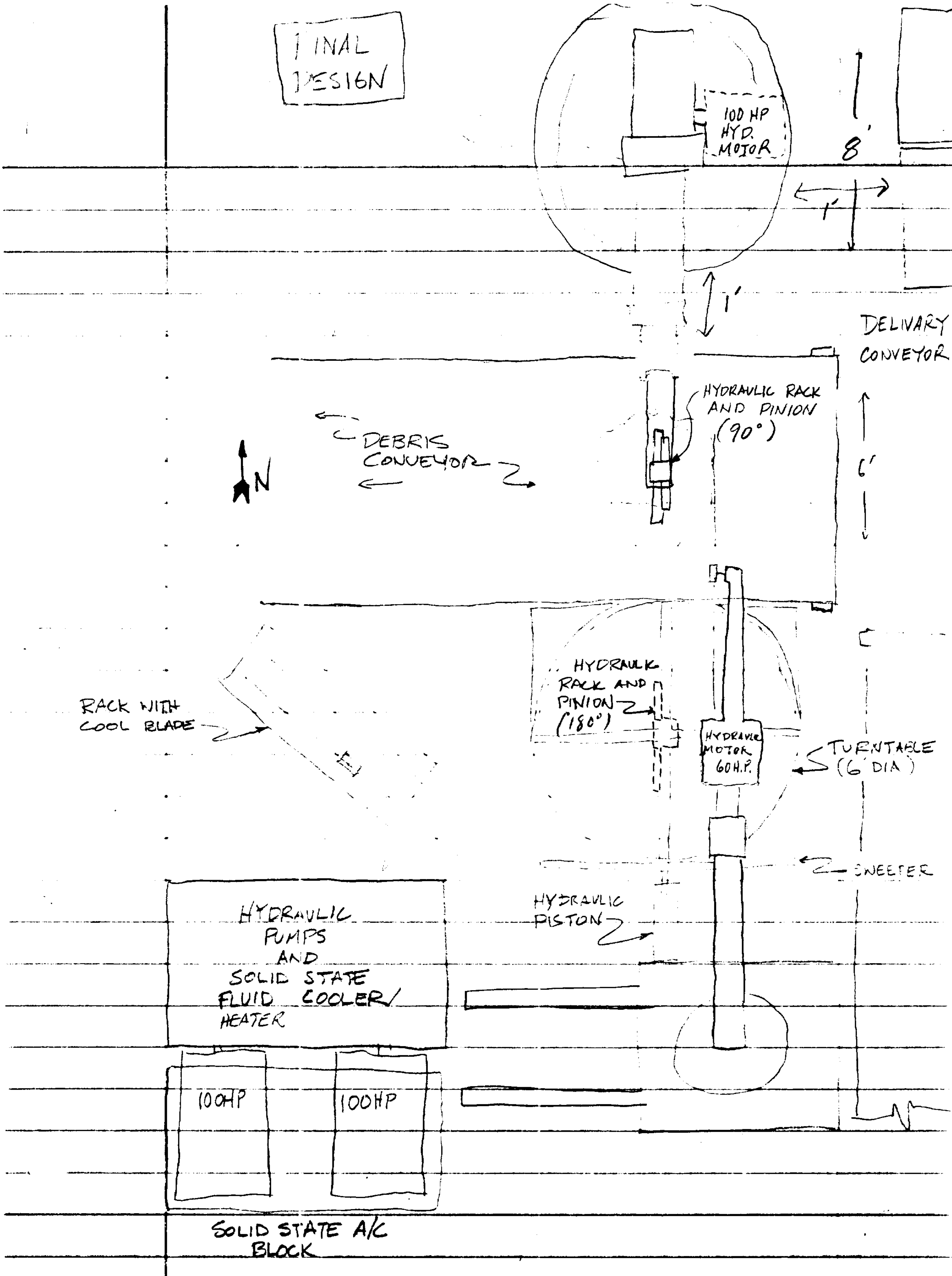
FINAL DESIGN



6' is the max possible length of cut if boulders are limited to ≤ 6' diameter

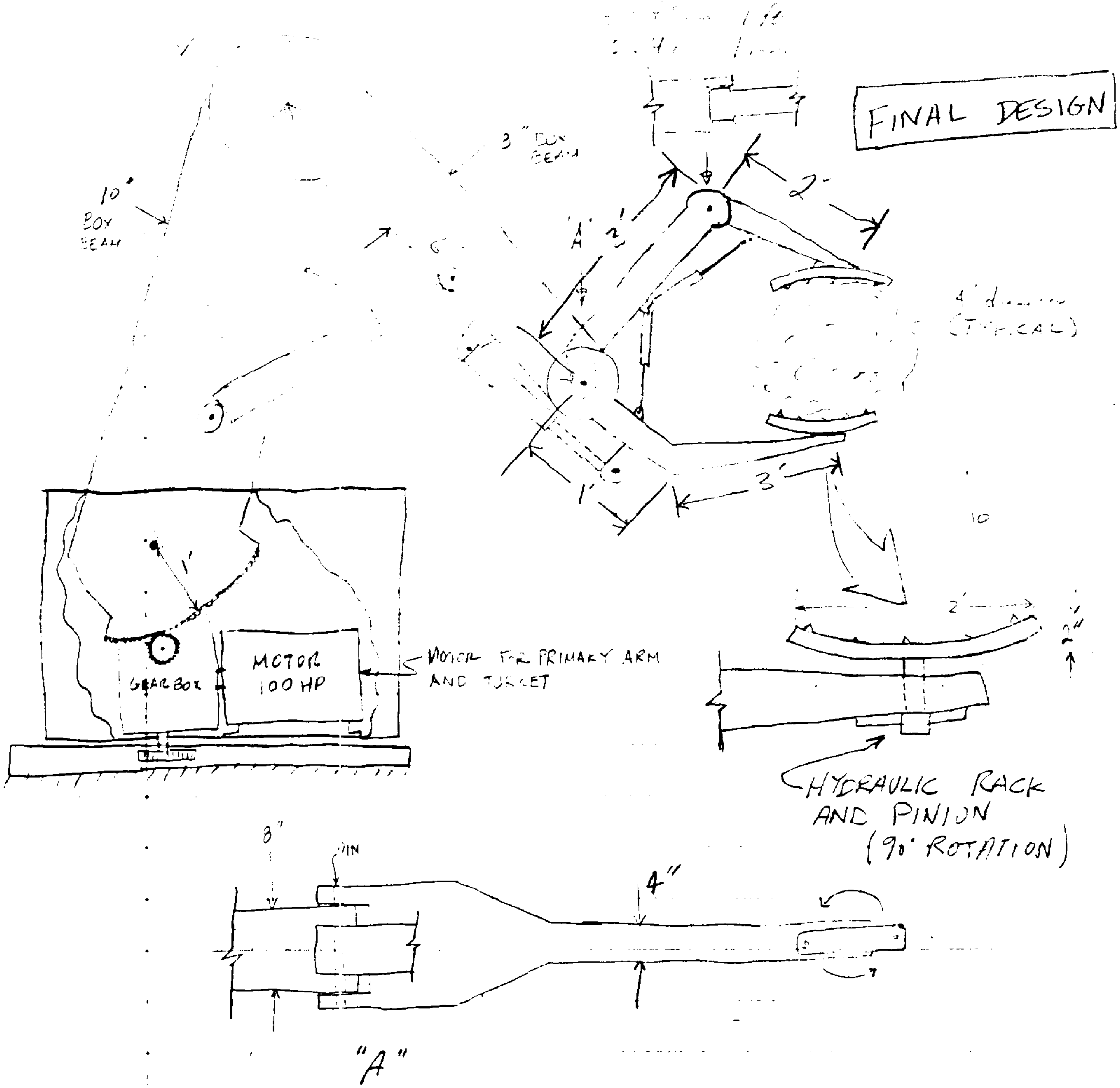


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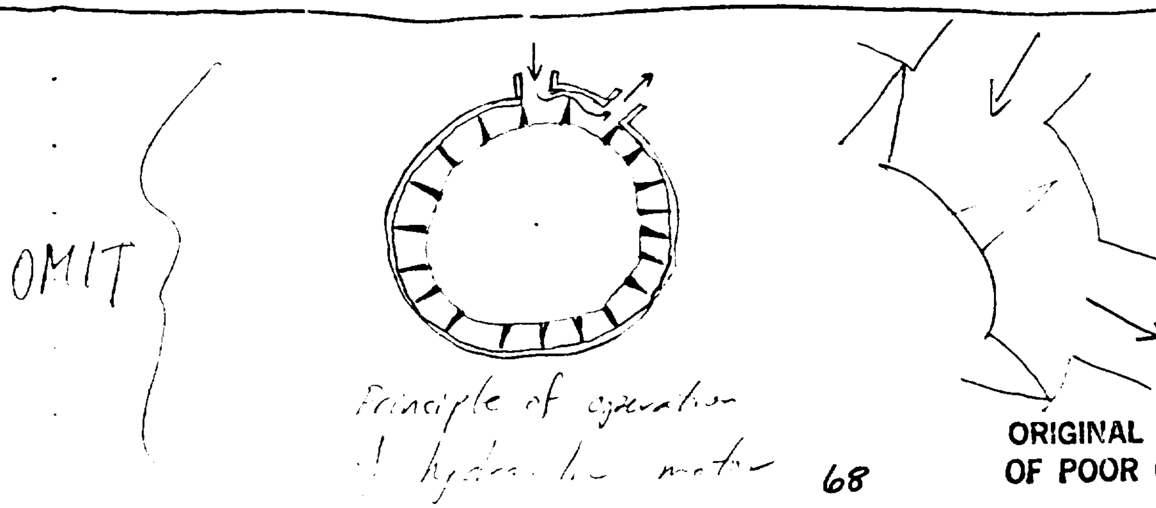


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FINAL DESIGN

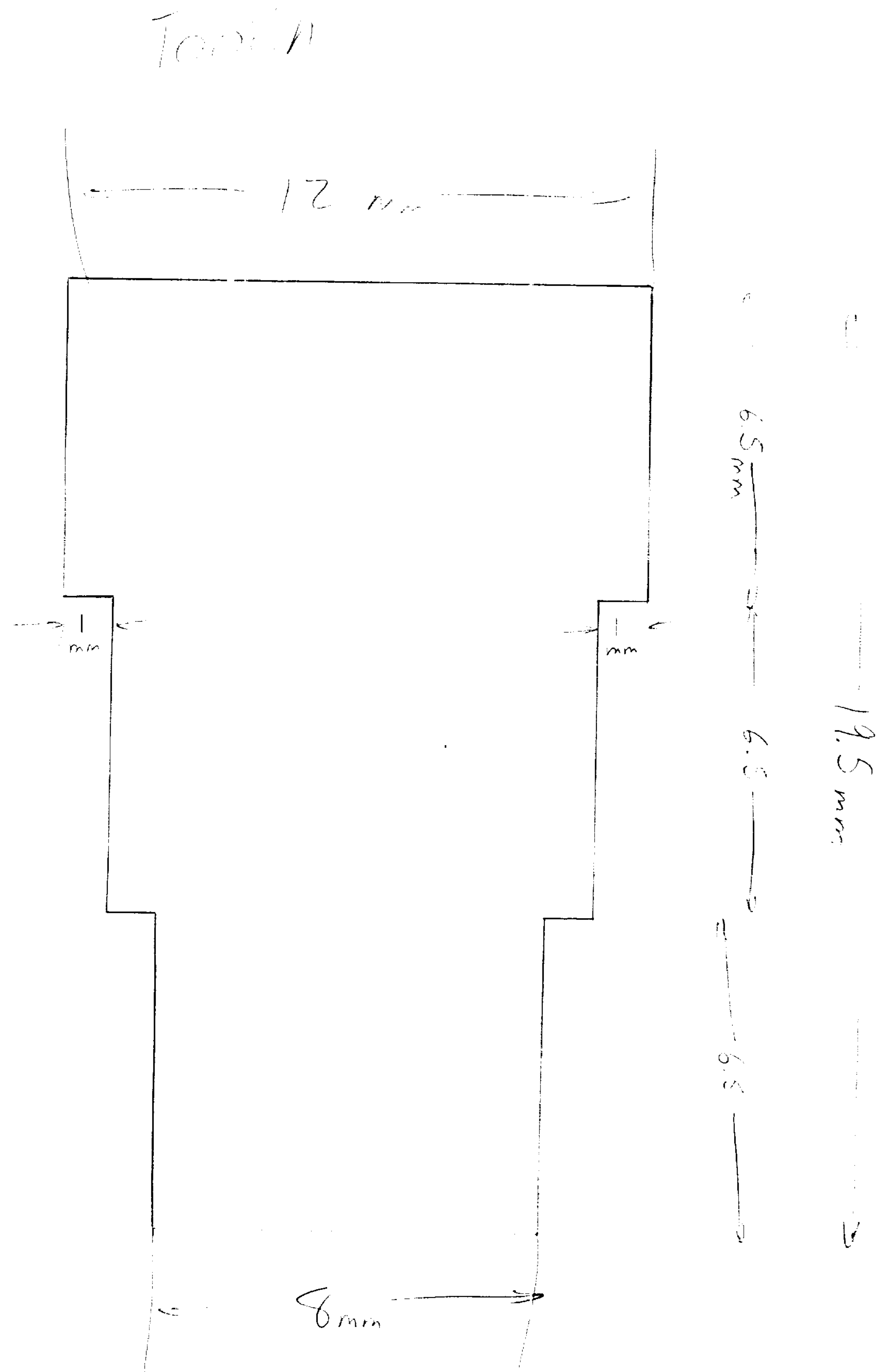


MATERIAL : Aluminum 6061-T6 (Structural members)



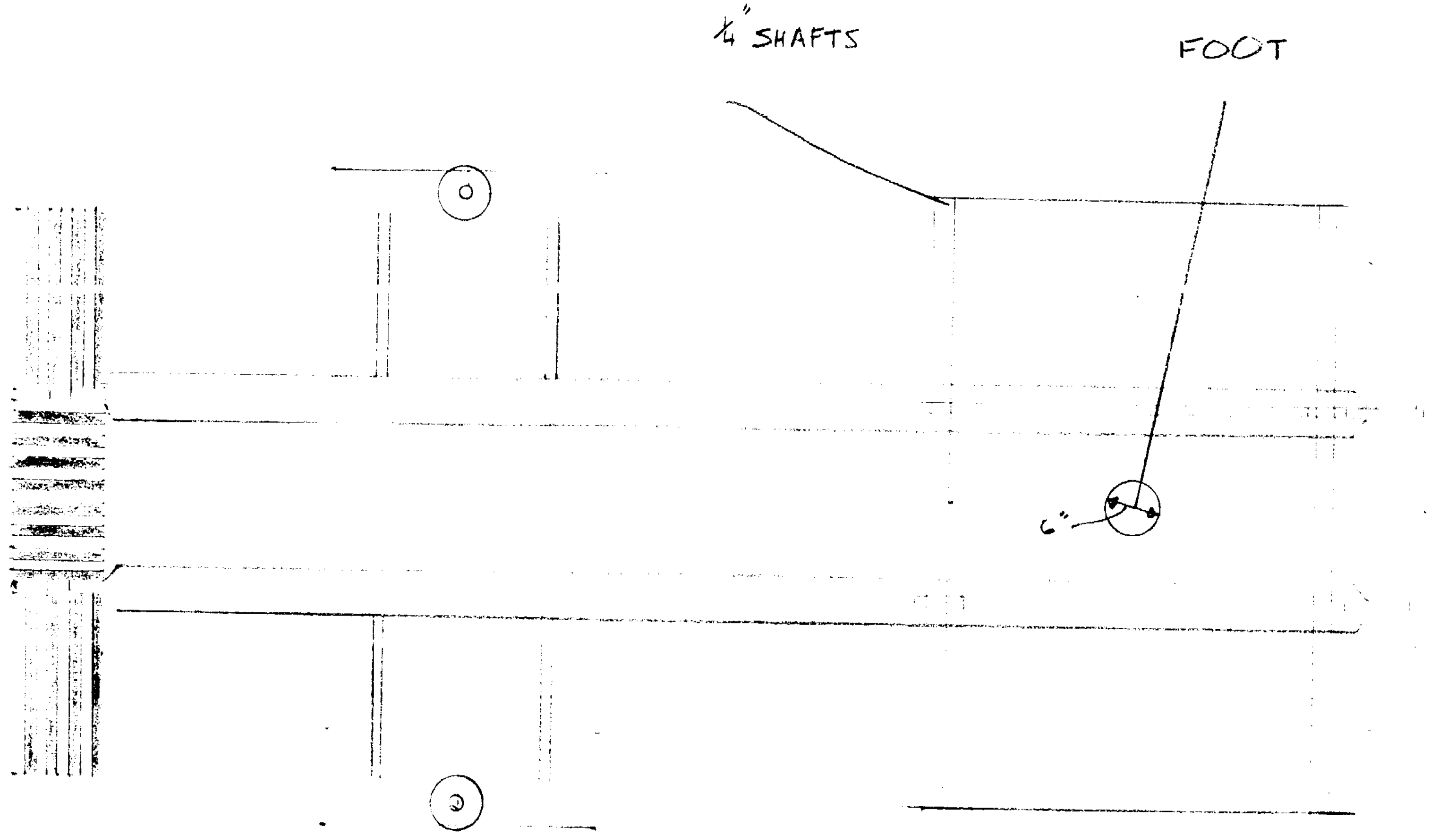
Principle of operation of hydraulic motor

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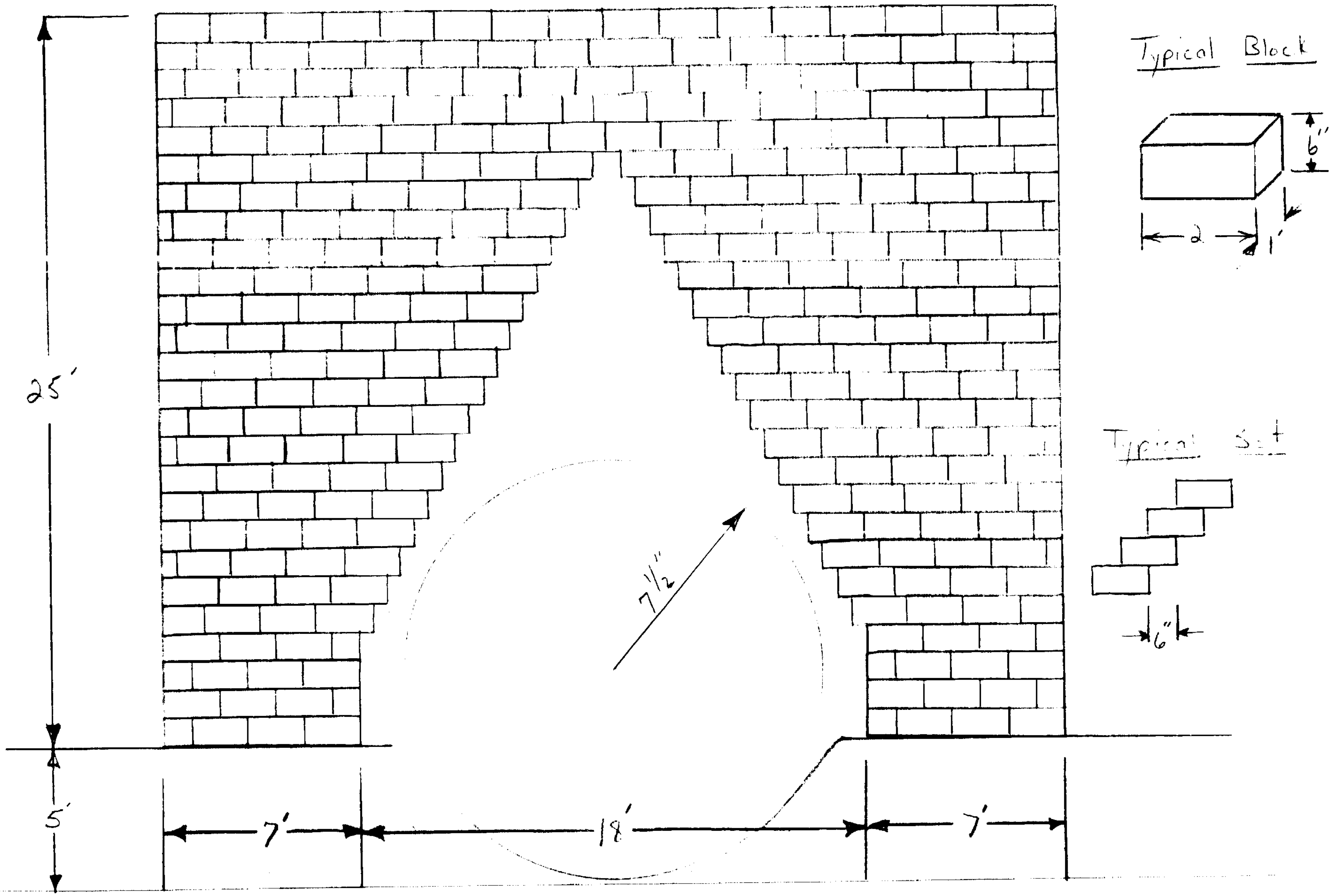
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TOP VIEW



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A TYPICAL BUILDING (25'x32'x60')
(END VIEW OF OPEN END)



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